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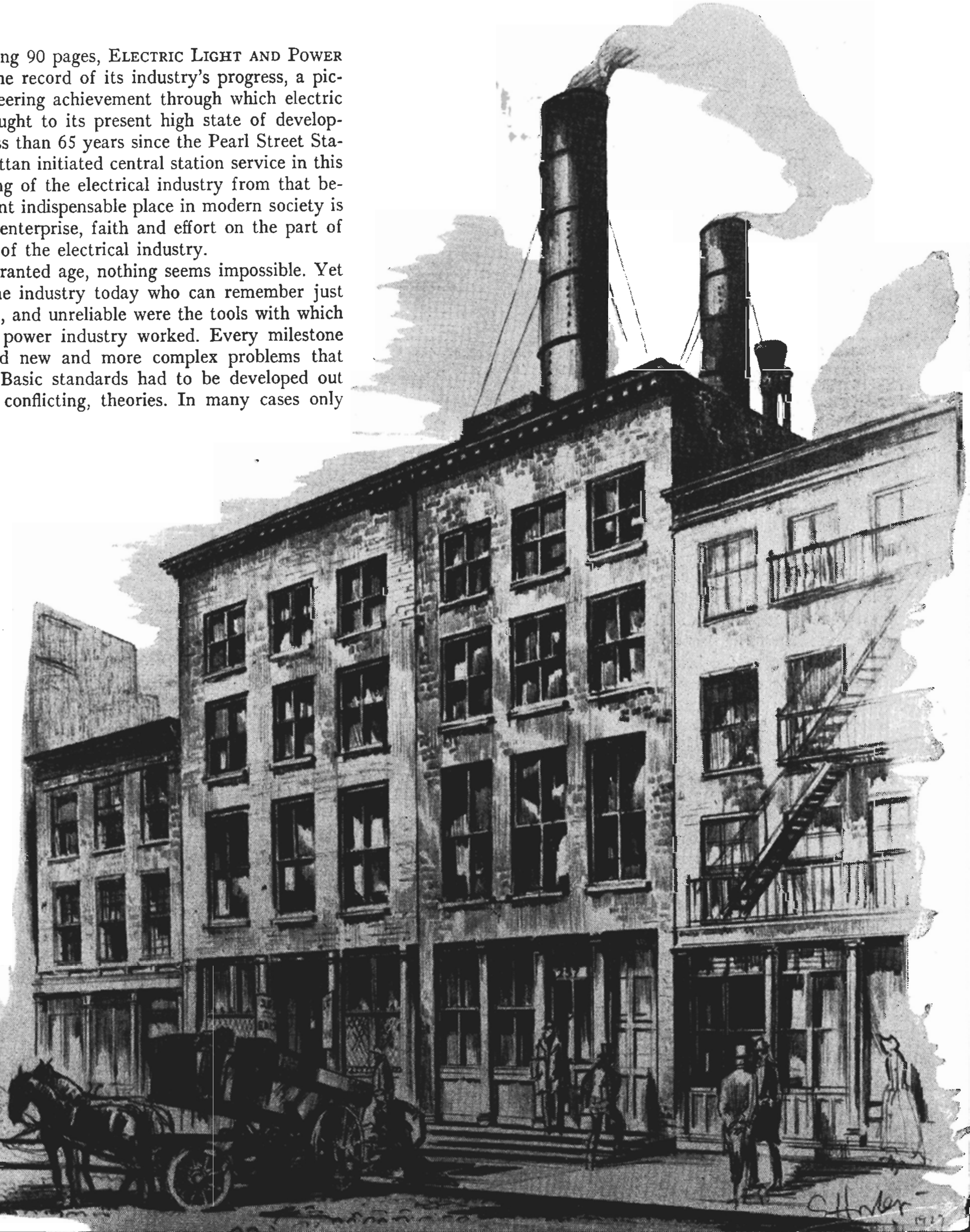
# PIONEERING IN ELECTRIC SERVICE

***A Pictorial History of the Significant Developments of the Electrical Power Industry Dedicated to the Electric Operating Companies as a Tribute to their Untiring Efforts in Converting the Scientific Advances of the Past Sixty-five Years Into Useful Public Services.***

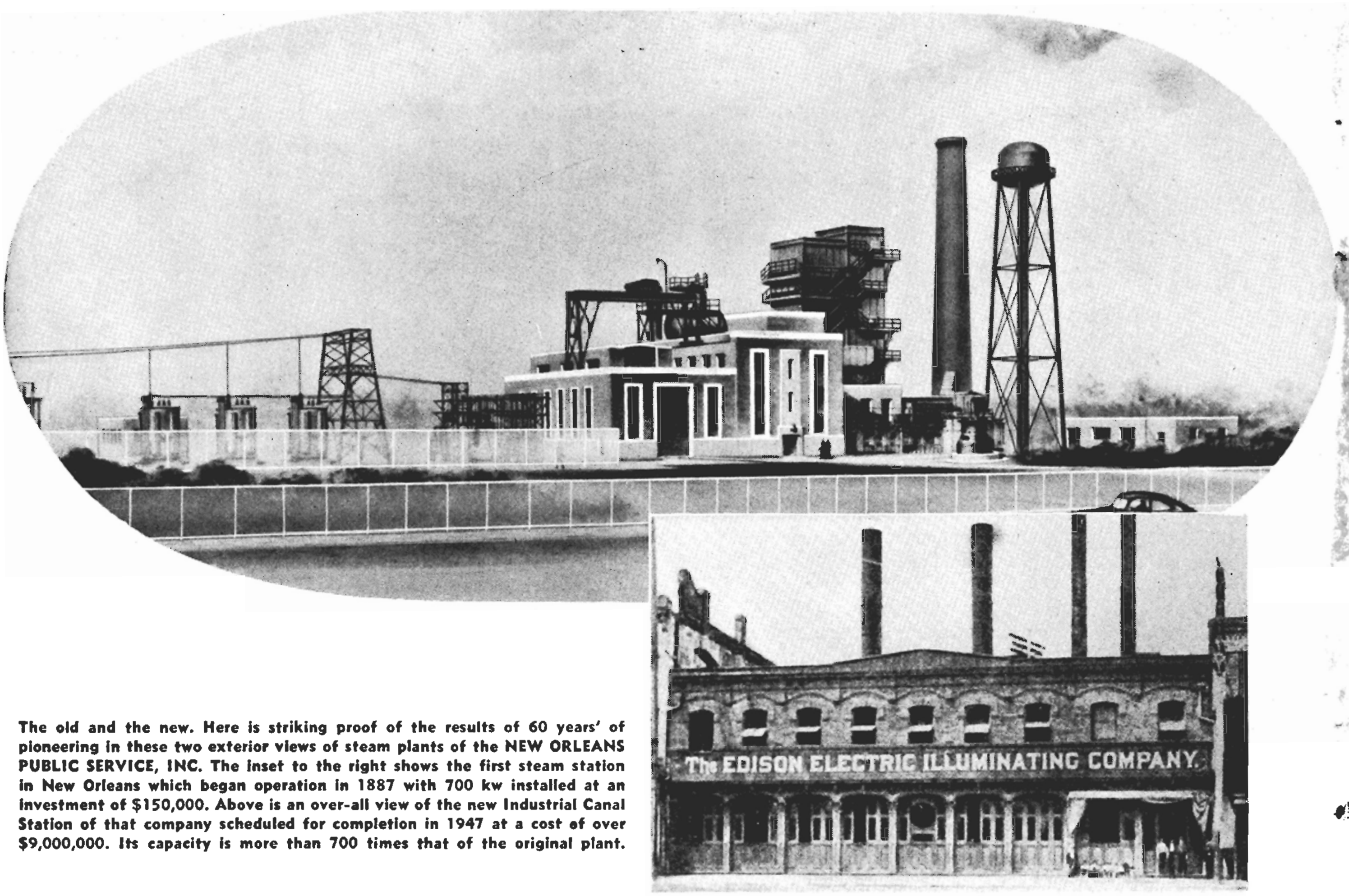
ON THE following 90 pages, ELECTRIC LIGHT AND POWER presents, for the record of its industry's progress, a pictorial review of pioneering achievement through which electric service has been brought to its present high state of development. It has been less than 65 years since the Pearl Street Station in Lower Manhattan initiated central station service in this country. The flowering of the electrical industry from that beginning into its present indispensable place in modern society is a saga of unflagging enterprise, faith and effort on the part of the men and women of the electrical industry.

In this taken-for-granted age, nothing seems impossible. Yet there are those in the industry today who can remember just how crude, inefficient, and unreliable were the tools with which the founders of the power industry worked. Every milestone of progress presented new and more complex problems that had to be resolved. Basic standards had to be developed out of many, and often conflicting, theories. In many cases only



**Grandfather of all modern power stations, the famous Pearl Street plant which was placed in service in New York City on Sept. 4, 1882 by Thomas A. Edison.**

# PIONEERING *IN ELECTRIC SERVICE*



**The old and the new. Here is striking proof of the results of 60 years' of pioneering in these two exterior views of steam plants of the NEW ORLEANS PUBLIC SERVICE, INC. The inset to the right shows the first steam station in New Orleans which began operation in 1887 with 700 kw installed at an investment of $150,000. Above is an over-all view of the new Industrial Canal Station of that company scheduled for completion in 1947 at a cost of over $9,000,000. Its capacity is more than 700 times that of the original plant.**

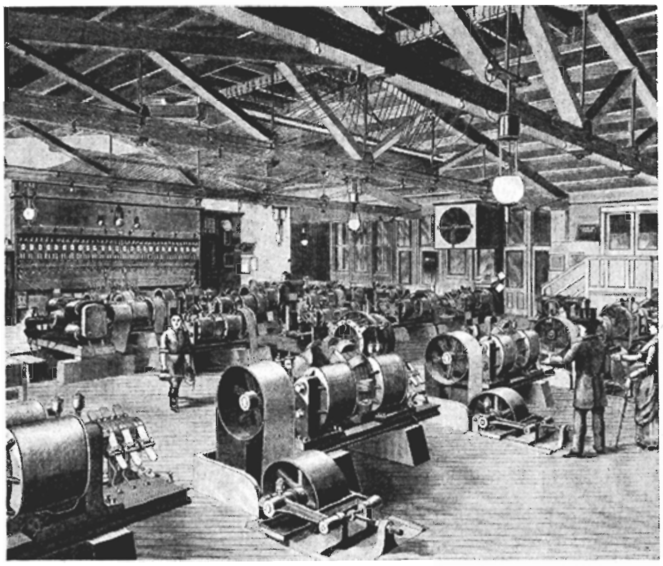
by trial and error could it be determined whether or not certain ideas were worthy of further exploration. Generally popular approval was accorded an idea, not because it was perfect, but because it was the best compromise between the advantages and disadvantages of other theories or designs that had been offered. Nothing came easy for those who had the temerity to launch a wholly new industry, for which even the terminology had to be devised.

In building the electric power industry, an unrelenting battle has been waged to unlock scientific secrets, to overcome economic factors, to create public acceptance for the ever-increasing number of electric servants, and to provide ever-better service at ever-decreasing rates.

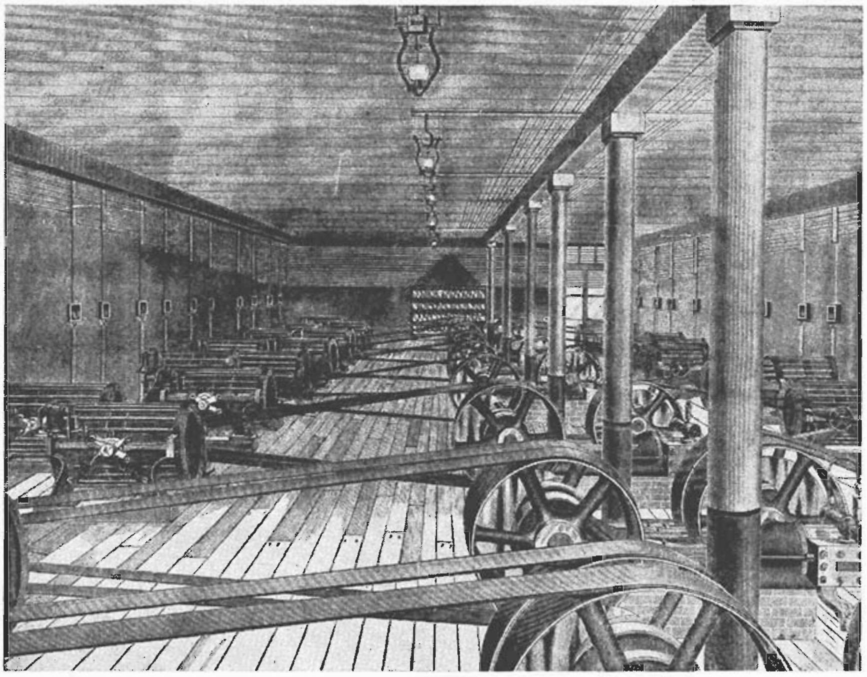
Teamwork between the electric operating companies and the manufacturers of electrical equipment has been a major factor in the rapid development of better and more efficient equipment, apparatus, and appliances. It devolved upon the power companies to take the new designs of the manufacturers and to put them to work for better service to the customer. Often these pioneer installations involved a large financial gamble. Again progress would seem stymied by an apparently insurmountable engineering obstacle. Always, however, some new process, or some new material, or some new theory would be

*(Continued on page 207)*

**Arc light stations antedated incandescent plants by about three years. Here is an interior view of the Brush Arc Light Station in Philadelphia which was placed in service in 1881 and was one of approximately 400 different companies in the Philadelphia area that were eventually consolidated into the present PHILADELPHIA ELECTRIC CO.**



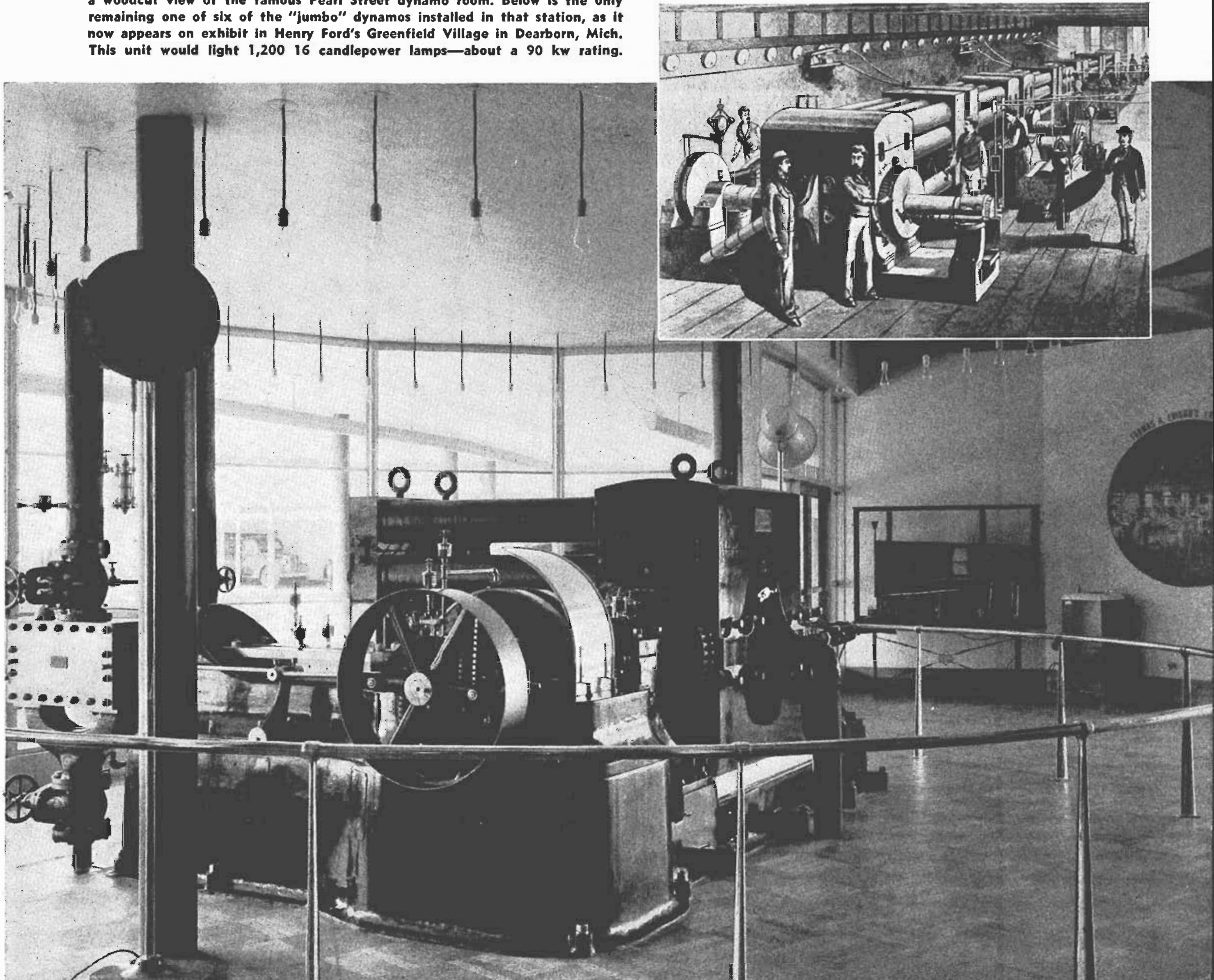
# Early Power Stations

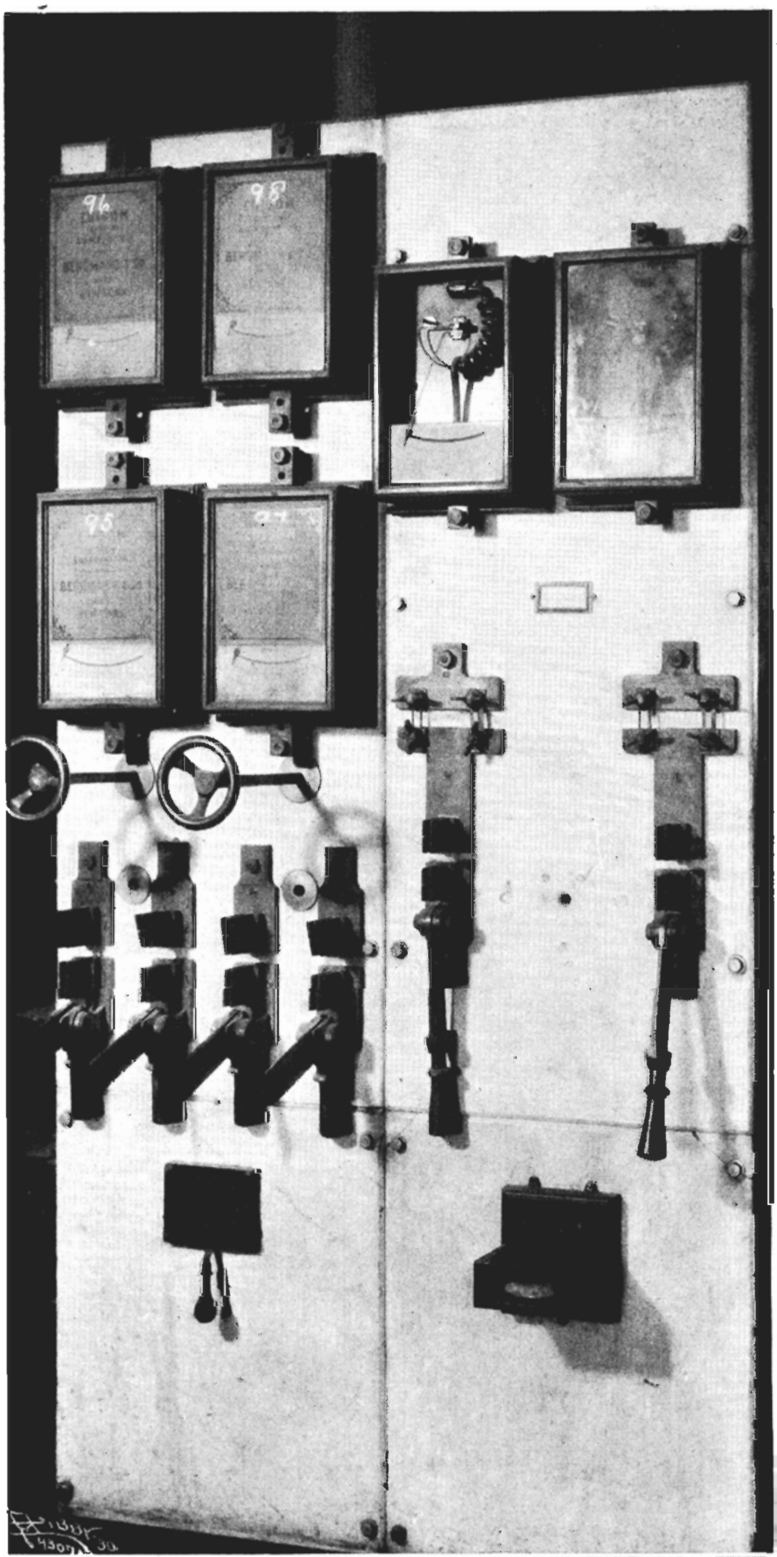


Another early arc light system was developed by the Thomson-Houston Company. This woodcut shows the interior of the Boston, Mass. installation in 1884. Two hundred arc lamps were operating from this station at that time.

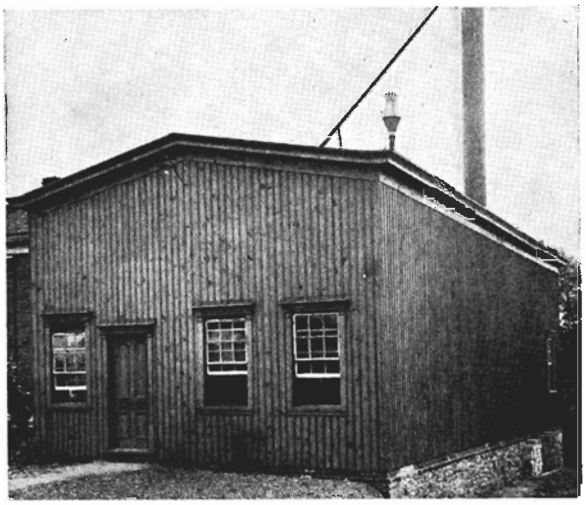
*(Woodcuts on these two pages courtesy of General Electric Co.)*

The Thomas A. Edison direct current system, destined to displace the arc light stations because of greater flexibility in the utilization of electric current, went into commercial service in New York City Sept. 4, 1882. The inset shows a woodcut view of the famous Pearl Street dynamo room. Below is the only remaining one of six of the "jumbo" dynamos installed in that station, as it now appears on exhibit in Henry Ford's Greenfield Village in Dearborn, Mich. This unit would light 1,200 16 candlepower lamps—about a 90 kw rating.

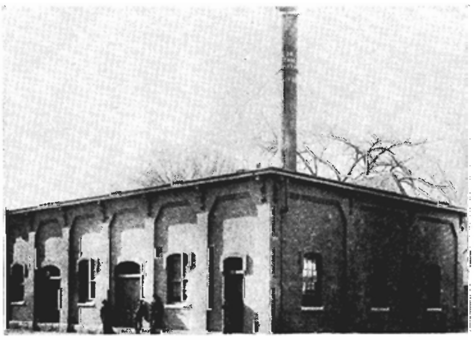




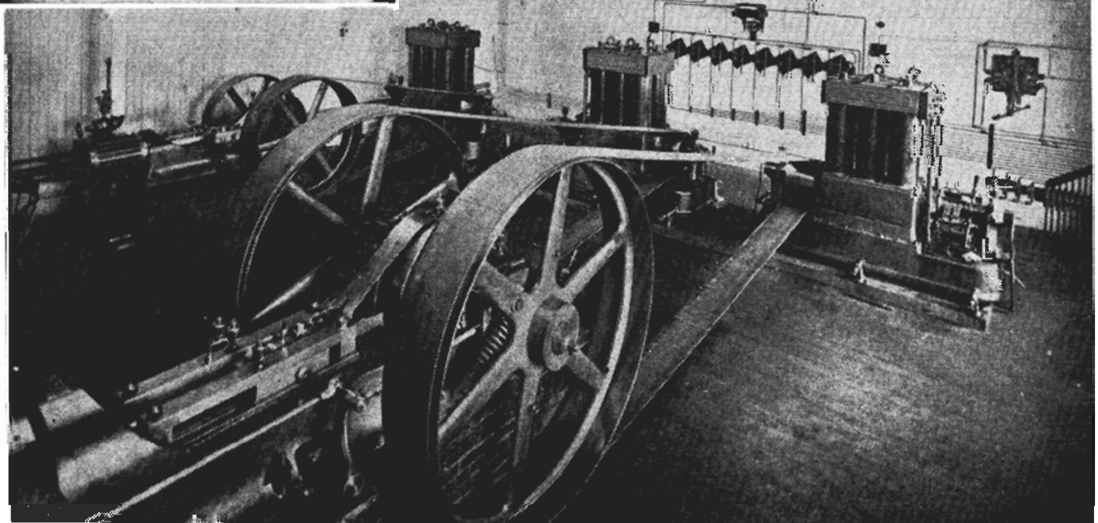
**This photograph supplied by the WASHINGTON WATER POWER COMPANY, shows an early d-c switchboard, apparently for two d-c generators and four distribution circuits. Of particular interest are the open type fuses on the main generator switches and current-indicating instruments of the Edison magnetic type.**



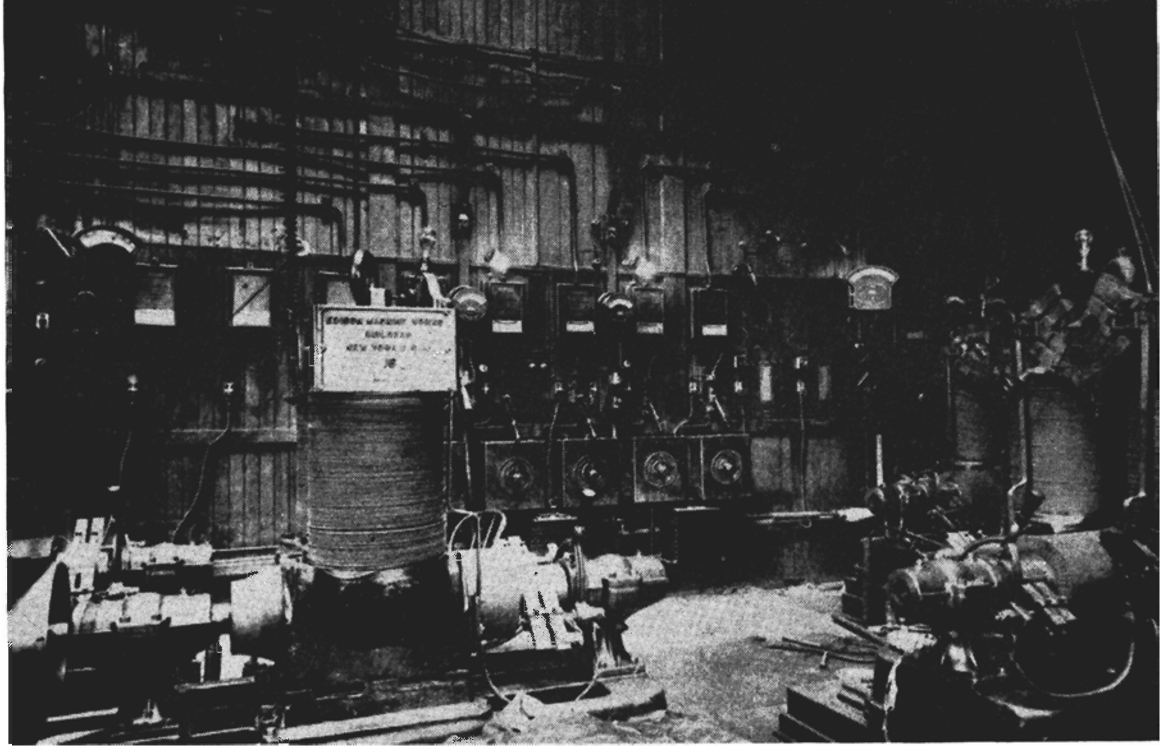
**This steam plant, which started operation on July 4, 1883, in Sunbury, Pa. (now served by the PENNSLVANIA POWER AND LIGHT CO.) marked a significant advance in distribution economy, being the first three-wire d-c installation, a circuit arrangement which cut copper requirements in half.**

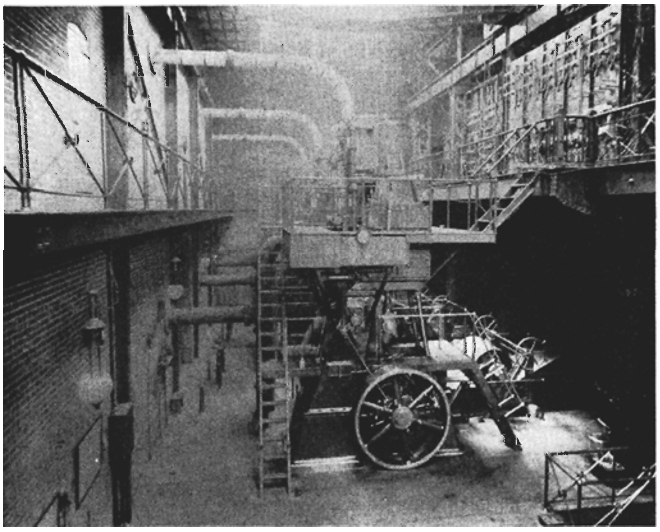


**This interior view of the original station of the BROCKTON EDISON COMPANY, Brockton, Mass., gives a particularly clear concept of arrangements in early stations showing the small d-c generators belted to reciprocating steam engines. Above is an exterior view of this station.**



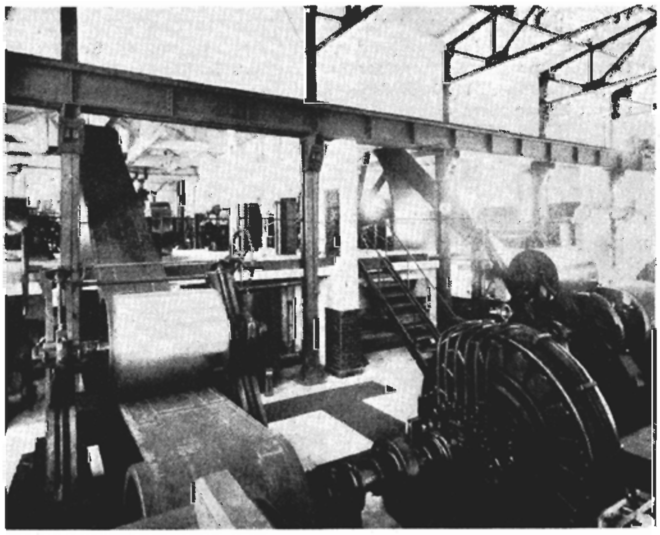
**Many things had to be improvised in the development of early power stations. Here is an excellent interior view of one such station taken in the early 80's and supplied by the KANSAS POWER AND LIGHT COMPANY, Topeka, Kan. Rheostats, meters and switches were mounted directly on the wall with exposed wiring supported by cleats. The name plate on the Edison bipolar machine in the left foreground carries serial number 16.**





**Canal Road Plant of the CLEVELAND ELECTRIC ILLUMINATING COMPANY as it appeared in 1895. Growth in technology and acceptance of the industry is indicated by the 400 kw. dynamos installed. Of particular interest is the vertical type reciprocating prime mover.**

**Interior of HARTFORD ELECTRIC LIGHT COMPANY'S Pearl Street Station as it appeared in 1896. This marked another significant advance as being one of the early alternating current stations. Here steam driven alternators were successfully operated in parallel with hydraulic turbine driven alternators at a plant 11 miles away—a pioneering attempt at plant interconnection for greater efficiency and reliability.**

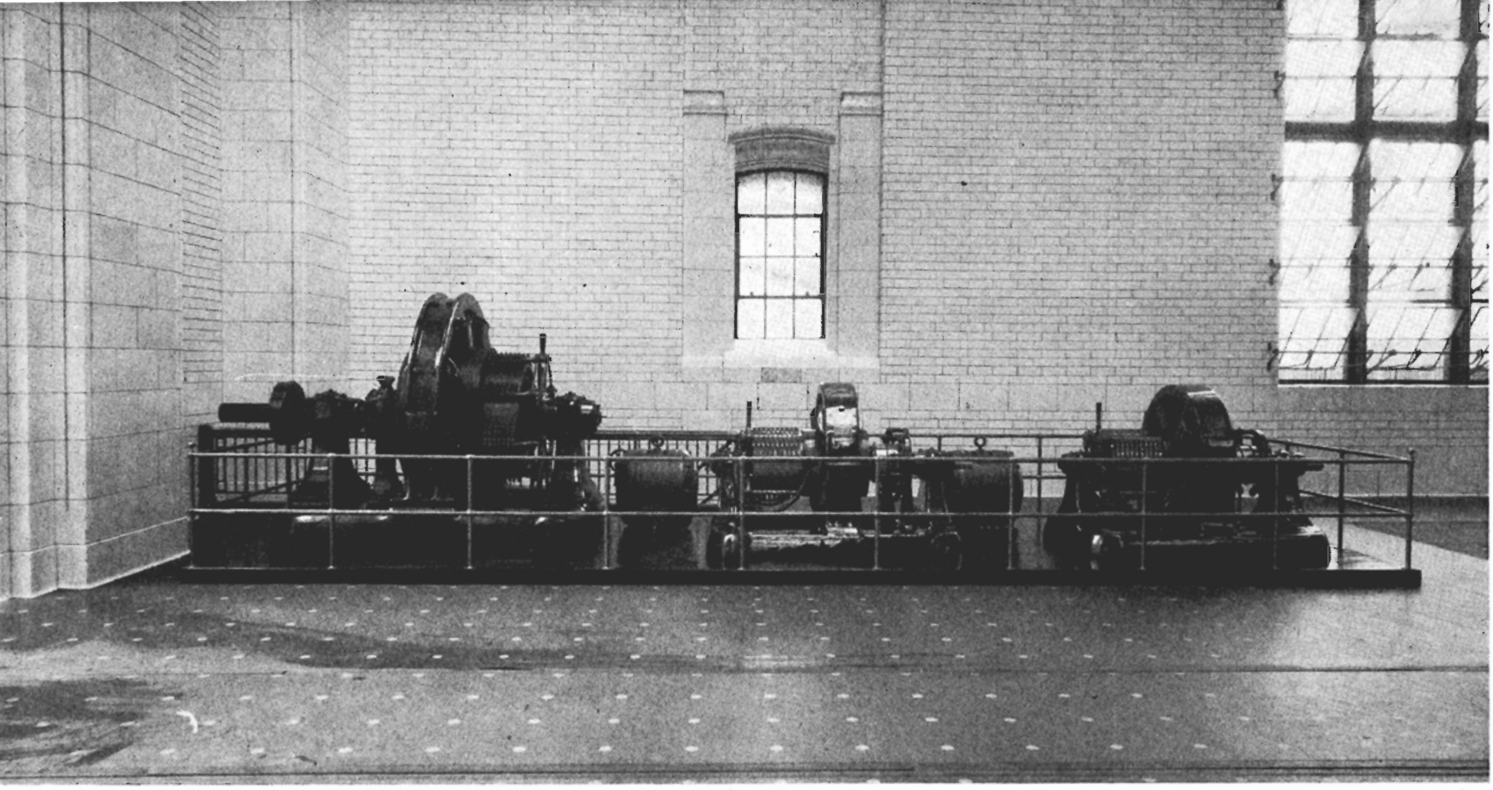


developed that pushed back the frontiers of growth and progress. It is these significant developments that the editors present in this pictorial history to the end that the modern pioneers in the industry may look back and take inspiration from the accomplishments of the first generation of power men.

## POWER PLANTS

In the early days of the industry, the tiny electric service organizations were pre-occupied primarily with generators and prime movers. The reciprocating steam engine of the early 1880's were ample in size to handle the generating units of the day. But, as demands for energy increased, and as the art of electrical design improved, a three-way race soon developed between boiler, steam engine, and generator designers, the net result of which was a rapid increase in capacity of individual generating units.

Compound, triple-expansion and even quadruple cylinder engines were applied to power the ever-increasing size of generators. To meet increased steam demands, two boilers were installed on either side of a firing aisle; then two more were added above the first two; in some multiple boiler installations, three storied boiler rooms were installed. By 1900, the reciprocating engines had become monsters with low pressure cylinders 8 ft in diameter and capacities of up to 8000 hp. Then a new form of steam drive arose to challenge the slow-speed engine. It was the high-speed steam turbine. Experimental turbine units had been imported from France and operated by the Consolidated Edison Company of New York in 1895. The first American turbine for central station service was installed on the Hartford Electric Company system in 1900, a 1500 kw unit. The compact design of this unit, as compared to a reciprocating engine drive of the same capacity is apparent from the pictures



**The need for plant interconnection among direct current stations, which originally served relatively small areas contiguous to the generators, became apparent in the 90's when greater reliability of service was desired, when larger and more efficient generators became available, and when load demands exceeded the capacity of the initial generator installations in a given area. System designers in the late 90's conceived the idea of transmitting power between d.c. stations by converting d.c. power to alternating current at high voltages through rotary converters, transmitting it to the desired area and reconverting to direct current in other converters. Pioneer equipment of this type, now on display at the Crawford Station of the COMMONWEALTH EDISON COMPANY, Chicago, is shown above. The 250 kw. unit on the left operated as an inverted rotary converter, transmitting power to the 100 kw. converters on the right, which were located several miles from the original station. This was a significant step toward concentrating power production in efficient stations and enlarging electric service areas.**

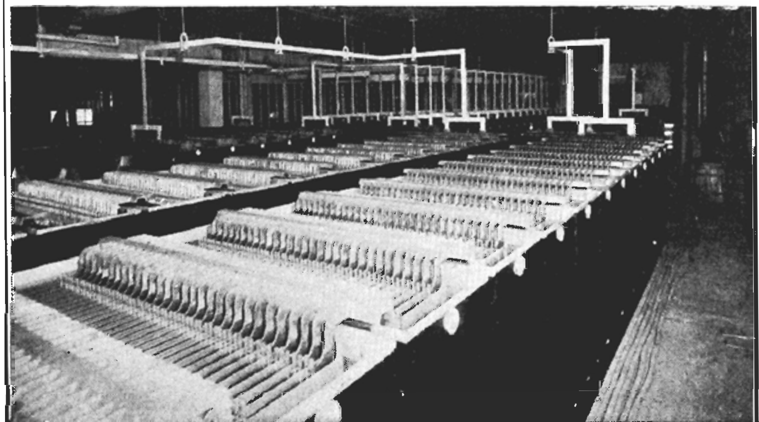
**1903. Now preserved by INDIANAPOLIS POWER AND LIGHT CO. as a major milestone in electric progress, this pioneer vertical Curtis steam turbine generator unit operated at Newport, R. I. from 1903 to 1927. Rated at 500 kw, 1800 rpm, the turbine was of the two-stage type, both stages having three cast-steel wheels shrunk onto the shaft, with a single row of buckets cut into the outer rim of each wheel.** ⇨

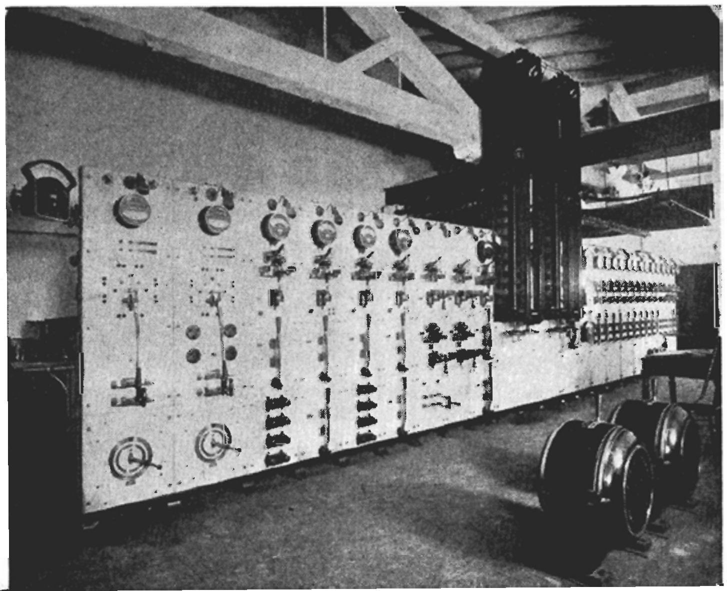
on page 210. This fact, plus savings in lubricating oil, maintenance and operating costs assured success for the newcomer although early units did not equal the fuel economy of the large steam engine.

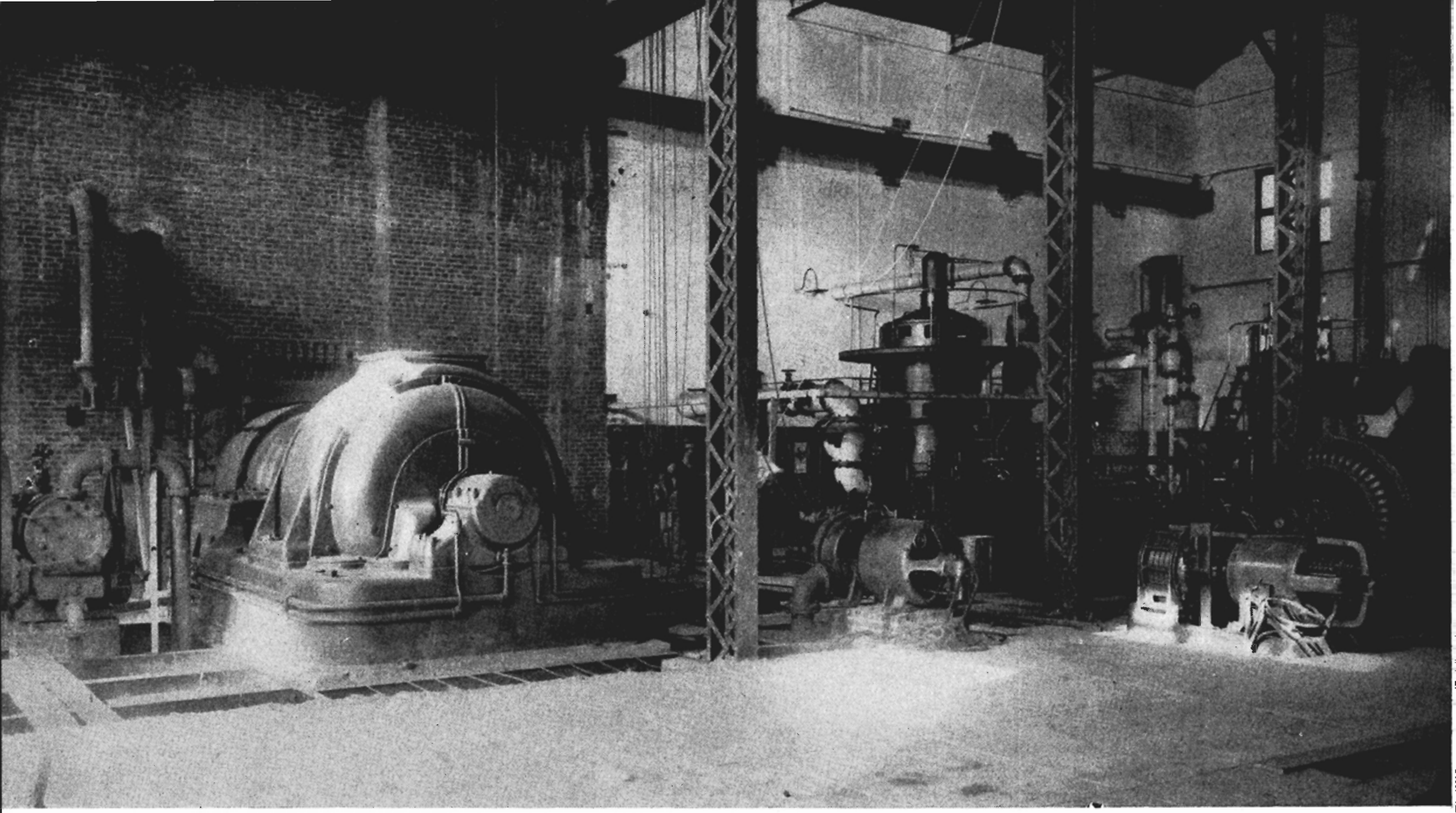
The Hartford installation was followed by the installation of a 5,000 kw vertical turbo-generator on the Commonwealth Edison system of Chicago. Shortly thereafter, still larger units were built, exceeding the capacity imposed by limitations of sheer physical size of the steam engine prime movers.

This advantage, plus improved efficiency, assured supremacy for steam turbines in the central station field. However, as the sizes increased, definite physical limitations on the capacity of the vertical turbine appeared in the form of the suspension of

**Storage battery installations were used in the early 90's both as standby power sources and to carry peak loads above the capacity of the generating units. These two views show HARTFORD ELECTRIC'S storage battery installation in 1896 and the switchboard with the storage battery end-cell switches mounted vertically near the center of the board. Large storage battery installations are still in use today on many systems, although the extension of direct current service areas has long been abandoned in favor of alternating current.**







**Installation of an early design of horizontal turbine-generator unit (left) was underway when this picture was taken about 1910 in the Raleigh Plant of the CAROLINA POWER AND LIGHT CO. In the background may be seen a vertical steam turbine installed many years earlier.**

the growing weight of the rotating element and the capacity to handle exhaust steam. Whereas the reciprocating engine could be built only up to 12,000 kw capacity, the vertical turbine could be built up to 20,000 kw. Horizontal turbo-generating units, however, continued to provide the larger and more efficient units required for the rapidly growing power industry. The horizontal design has been used exclusively since 1913 and single shaft units of 165,000 kw of capacity have been constructed.

### Research for Economy

Growth in the size of generating units was only one manifestation of the industry's continuing search for more efficient power production. In the Pearl St. station of 1882, 138,000 BTU's were required to generate a kilowatthour. Modern stations generate a kilowatthour with less than 10,000 BTU's. Between these two figures lie 65 years of intensive research and refinement in design of turbines, boilers, auxiliaries and generators. Another index of improved design is shown by the replacement of a 22,500 kw unit, installed 30 years ago, with a 100,000 kw unit—in essentially the same space.

While feedwater heaters, forced draft and mechanical firing aids were in use before 1900, it was not until 1910 that automatic stokers came into general use. Up until that time one man could fire a boiler by hand under favorable conditions. But, with increasing capacities, the tonnages of fuel involved required mechanized firing. Superheaters, which added extra BTU's to the steam from otherwise waste flue gases, were in use with early turbine installations and no modern steam plant is complete without one.

The years immediately following World War I were ones of intense activity for steam plant engineers. Up to that time generating units were selected primarily for the requirements of

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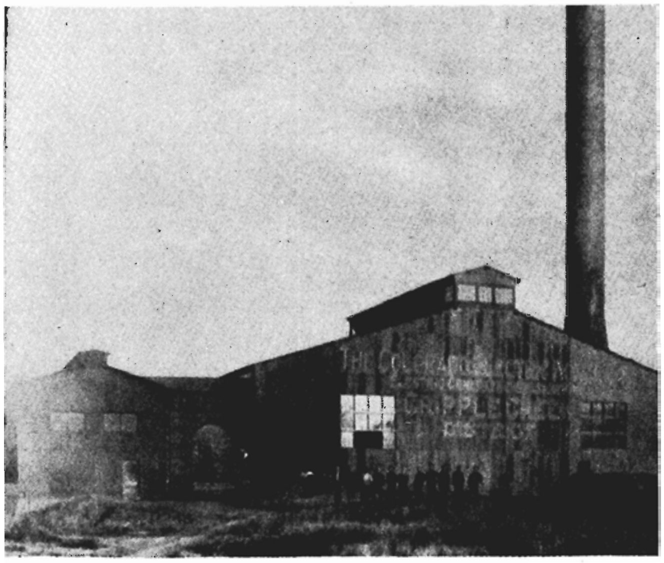
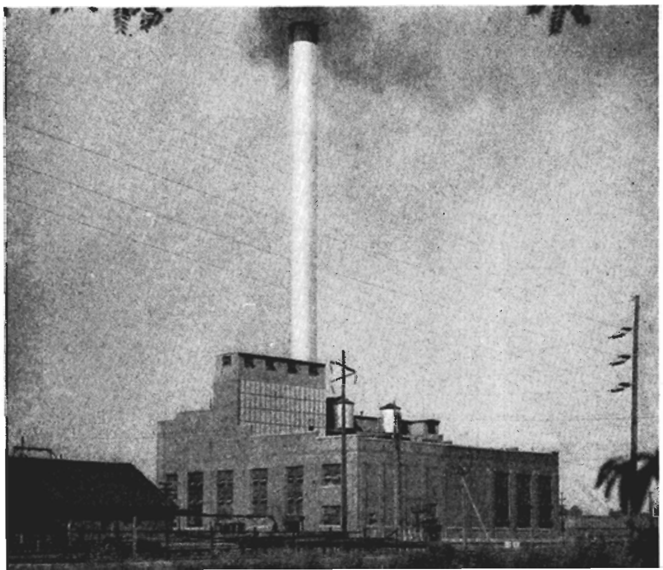
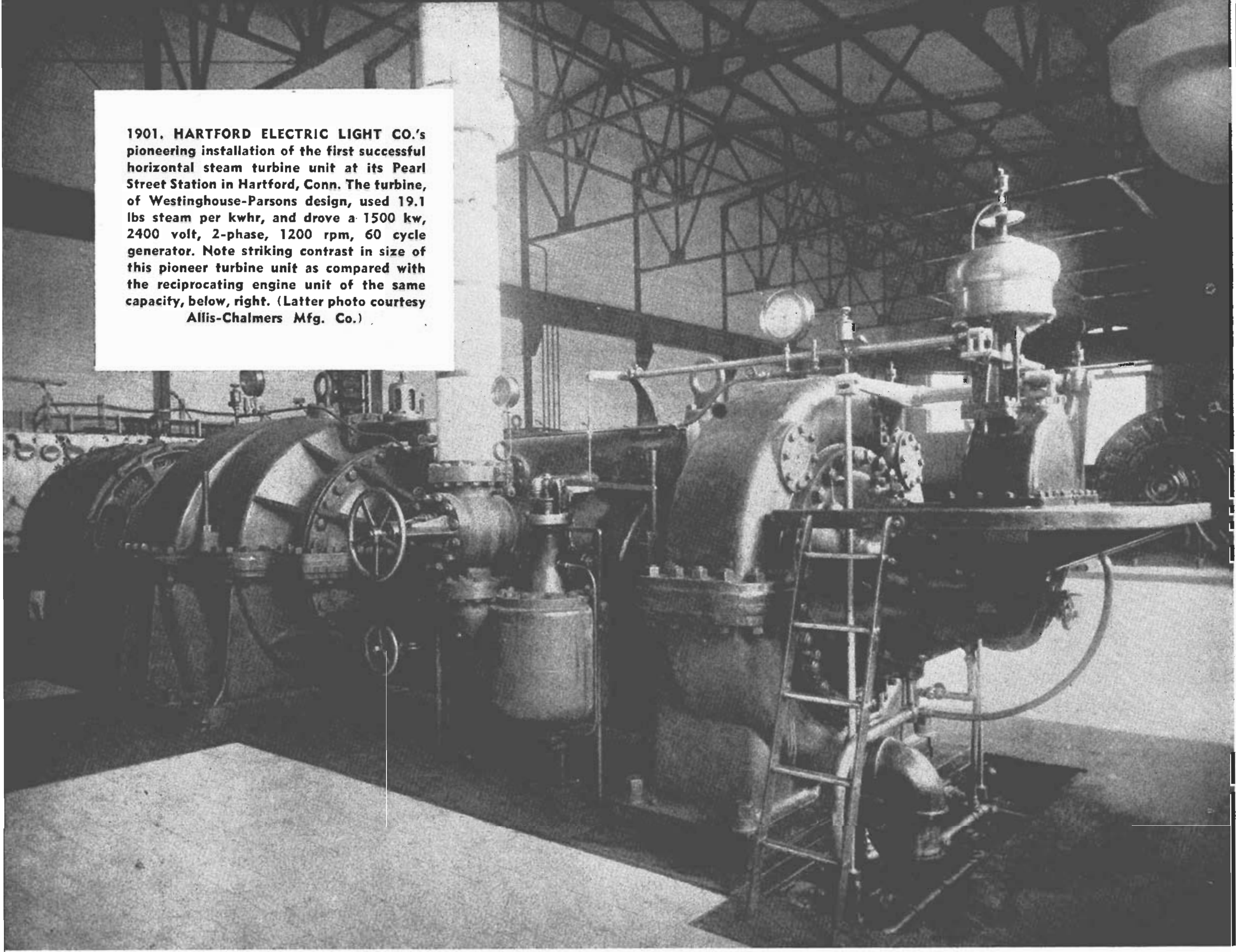




**1896-1941—Nearly a half century of progress in steam plant design and construction is depicted in these two views of plants on the system of the SOUTHERN COLORADO POWER CO. Top: Original Canon City, Colo., reciprocating engine plant. Below: The company's present plant at Pueblo.**



**1901. HARTFORD ELECTRIC LIGHT CO.'s pioneering installation of the first successful horizontal steam turbine unit at its Pearl Street Station in Hartford, Conn. The turbine, of Westinghouse-Parsons design, used 19.1 lbs steam per kwhr, and drove a 1500 kw, 2400 volt, 2-phase, 1200 rpm, 60 cycle generator. Note striking contrast in size of this pioneer turbine unit as compared with the reciprocating engine unit of the same capacity, below, right. (Latter photo courtesy Allis-Chalmers Mfg. Co.)**

local systems. In the 1920's the gradual interconnections of plants and systems injected other factors into the problem of power plant growth. The search for larger and more efficient units was aided by the perfection of pulverized fuel firing systems in the early 1920's and a concurrent development of water cooled furnace walls which enabled furnaces to withstand a greater heat release rate and consequently to produce steam at a much greater rate than heretofore. The economizer also was adopted to improve the utilization of heat. Metallurgy advances gave designers the chance to utilize higher pressures and by 1924, 600 psi stations had been installed. The practice of "bleeding" turbines of steam for feedwater heating became common. Combustion control equipment, which provided automatic adjustment of fuel, air and feedwater injection conforming to load fluctuations on the turbine, provided for more efficient plant operation than could be obtained with manual control.

Then a radical step was taken by the industry in the adoption of the high-pressure, super-position turbine. The first of these was a 1,200 psi, 3000 kw unit which exhausted to the steam supply of older and lower pressure turbine units. The success of this unit started a trend toward superposition because it gave renewed economic life to older stations, in effect using the steam twice in generating electricity and capitalizing on the increased efficiency of modern steam generating units.

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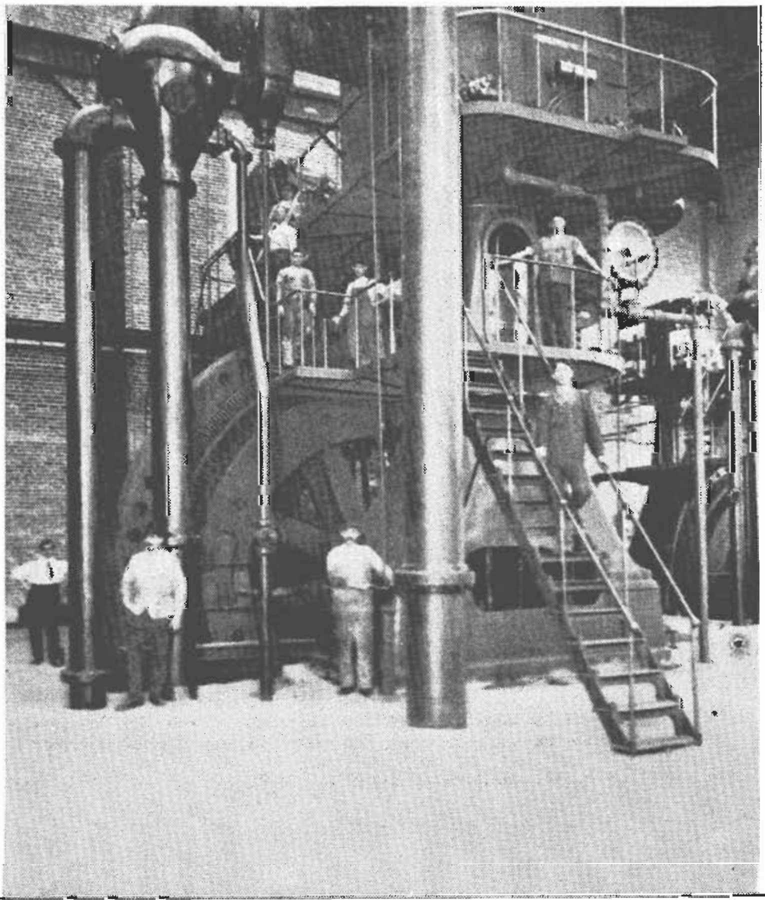
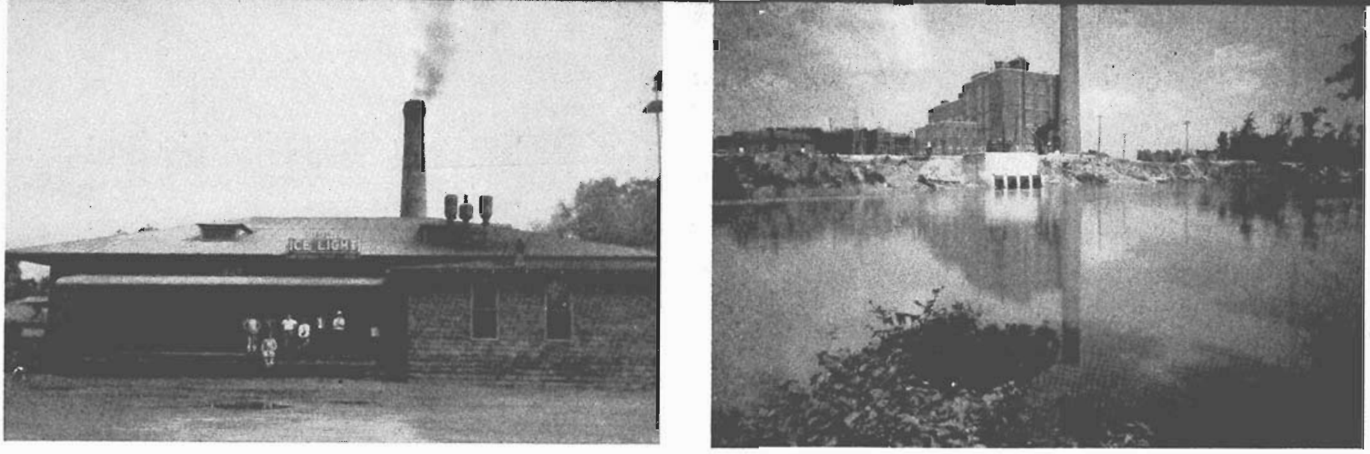
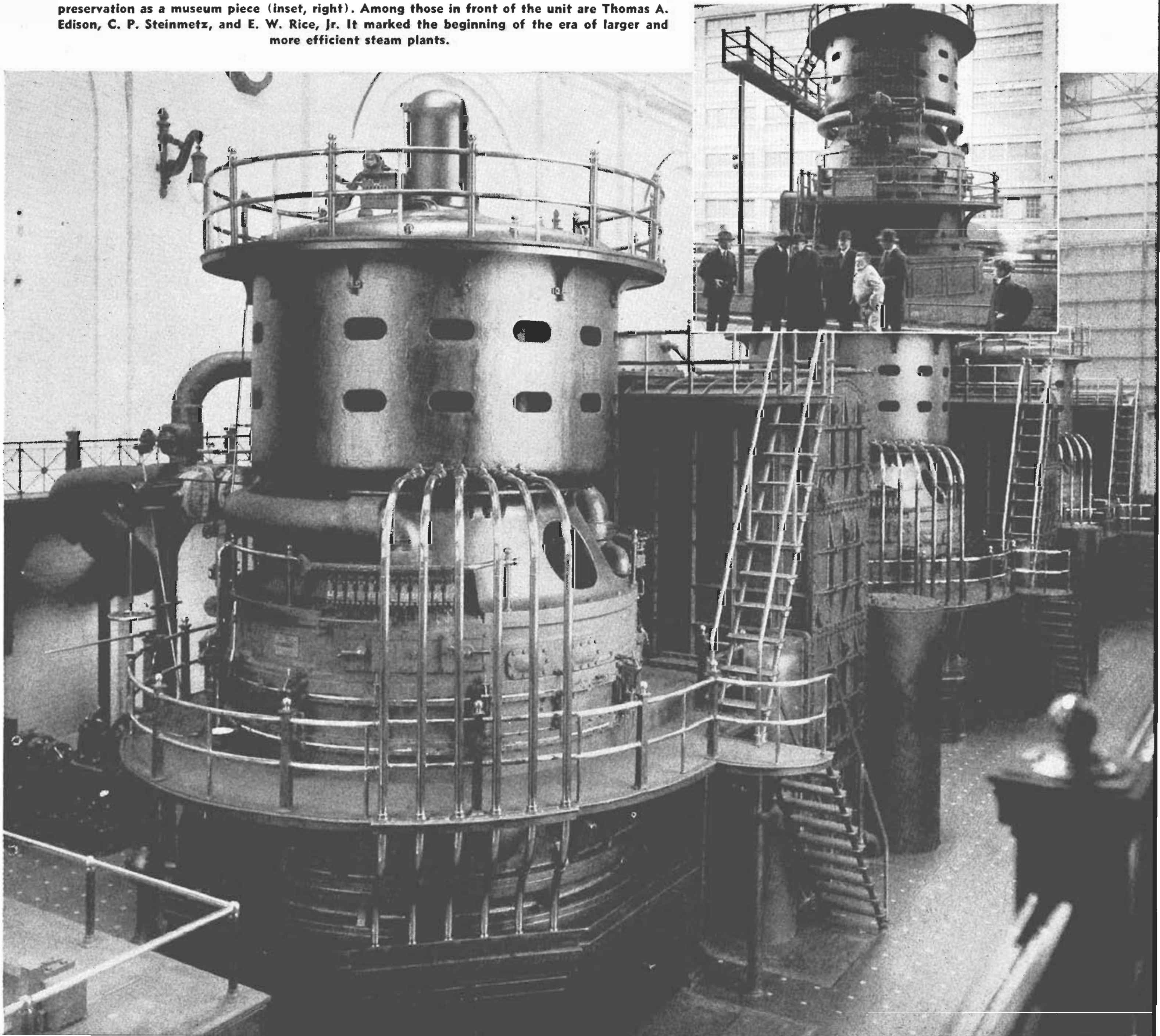
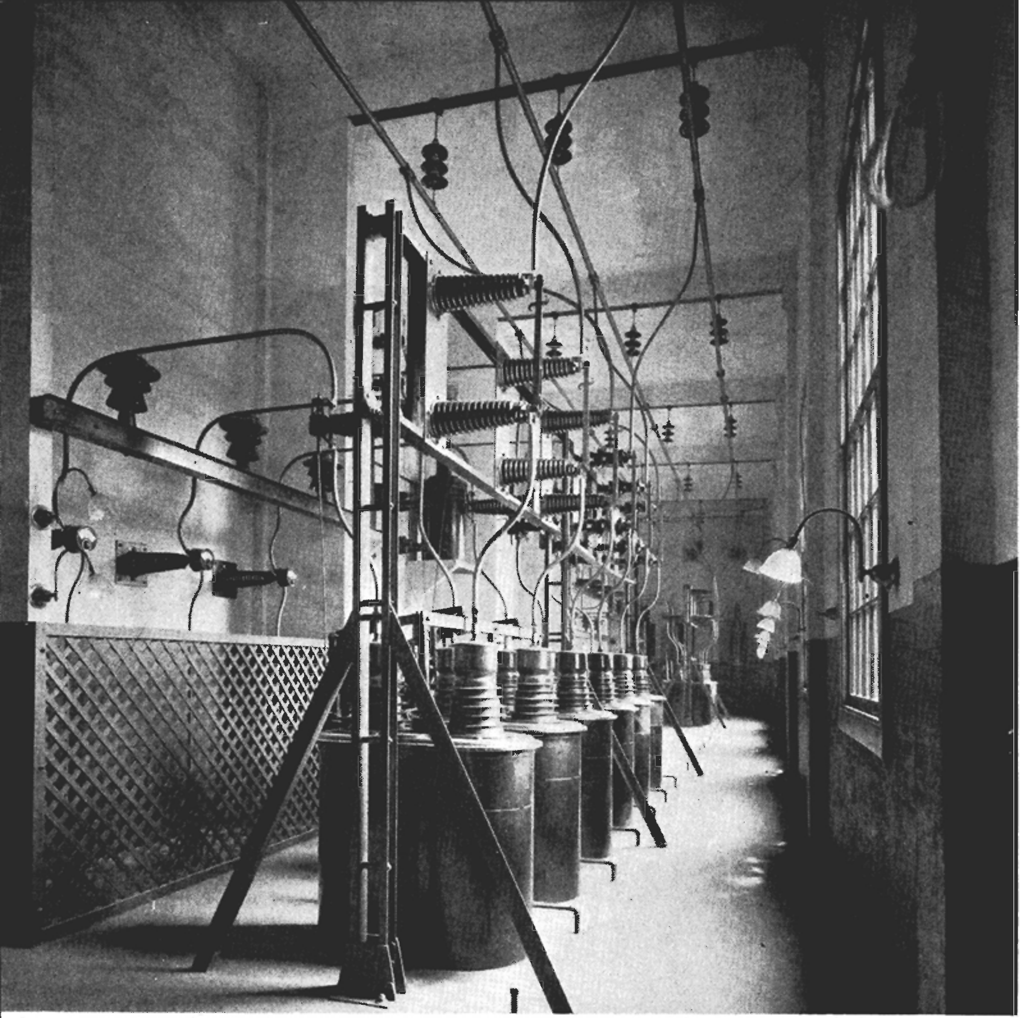




Combined facilities for dispensing ice and electric power, as was a rather common early practice, are typified by the early "Ice-Light" plant of the **MISSISSIPPI POWER CO.**, shown on the left. Right, the company's new Plant Eaton near Hattiesburg, Miss., a milestone in this company's steady development of a modern power system in an area which was served up to the early '20's with isolated generating plants of small capacity.

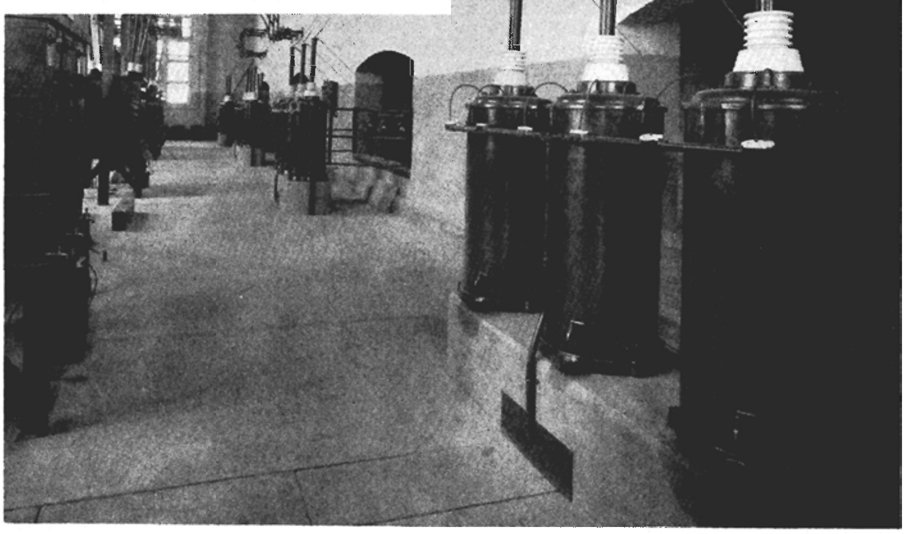
1903. This 5000 kw, 500 rpm, 5-stage, steam turbine generator (foreground) was the first large vertical Curtis unit to be placed in service. It operated at 175 psig, 495F, and was direct-connected to a 9000 volt, 3-phase, 25 cycle alternator. Originally installed in the Fisk Station by **THE COMMONWEALTH EDISON CO.**, it was ultimately moved to the General Electric plant for preservation as a museum piece (inset, right). Among those in front of the unit are Thomas A. Edison, C. P. Steinmetz, and E. W. Rice, Jr. It marked the beginning of the era of larger and more efficient steam plants.





**66-kv switch and bus room, in the Condit Station of the NORTHWESTERN ELECTRIC CO., featured such items of historical interest as the iron vane, bushing mounted ammeters on the left, the G.E. type E-10, 66-kv indoor oil circuit breakers in the foreground, with series overload trip units, and indoor electrolytic type lightning arresters, at the far end of room. The hazards to service and to operating personnel incident to exposed live parts is evident.**

**1906. Early designs of 60-kv oil circuit breakers utilized wooden tanks with metal braces (on the left) in this view of the switchroom of the Nine Mile Station of the WASHINGTON WATER POWER CO. Space requirements for the 60-kv current transformers on the right are in marked contrast with the modern designs. Note that porcelain breaker and transformer bushings had not yet appeared, impregnated fibre tubes being used.**



**1913. A 50-horse team was required to haul this turbine to a downtown plant of the NORTHWESTERN ELECTRIC CO. in Portland, Ore. This is indicative of some of the haulage problems on heavy equipment confronting engineers in the early days.**

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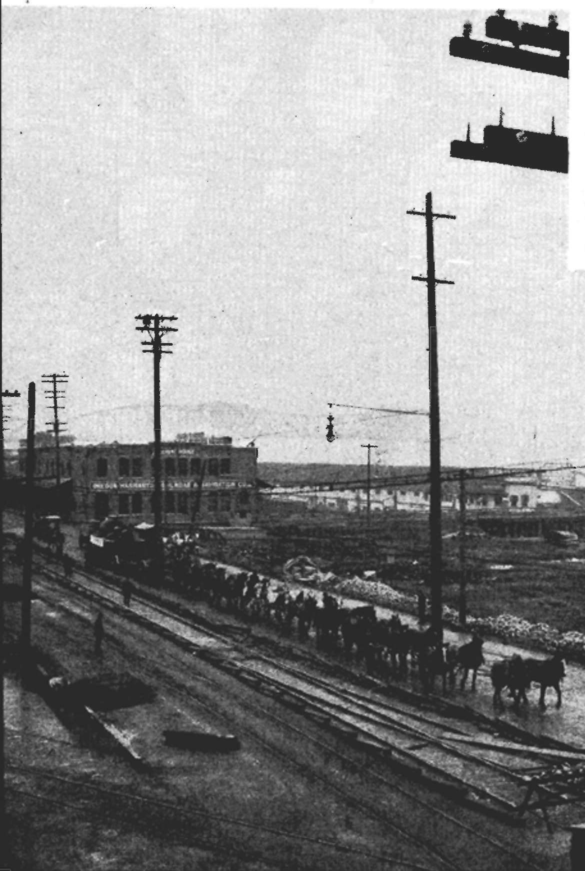

At the same time demands for extremely large units for use as intersystem base load power producers led to the development of double and triple element turbo-generators. A variety of designs became available; the tandem compound turbine consisting of a high pressure and low pressure turbine mounted on the same shaft; the cross compound, where the high pressure and low pressure units were essentially separate turbogenerator sets with the latter taking the exhaust steam from the former; and the vertical compound where the high-pressure unit was mounted on and directly above the low pressure unit. These designs reached their peak with the installation of the 208,000 kw cross compound unit at State Line Station in 1928, still the largest single generating unit in the world.

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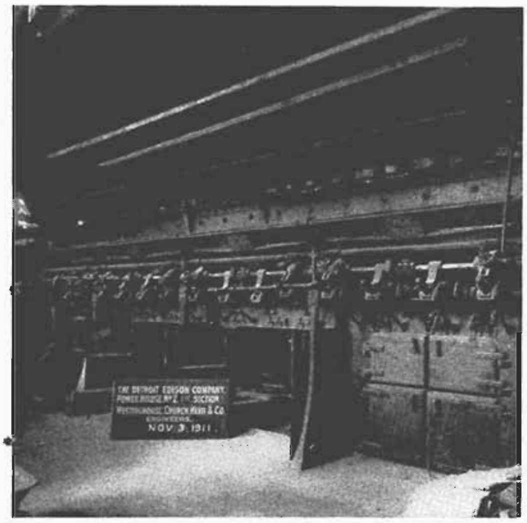
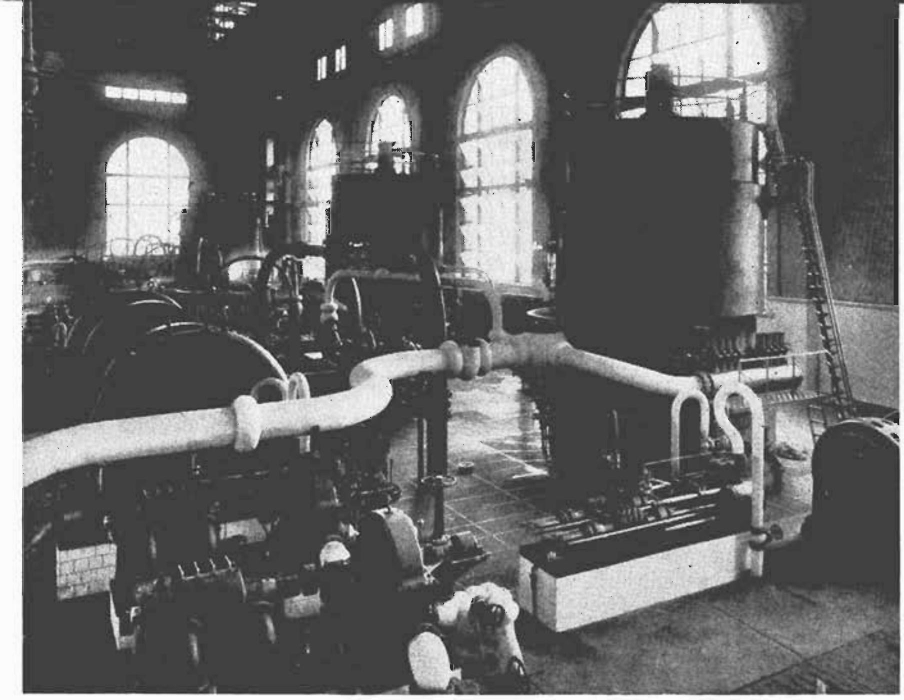
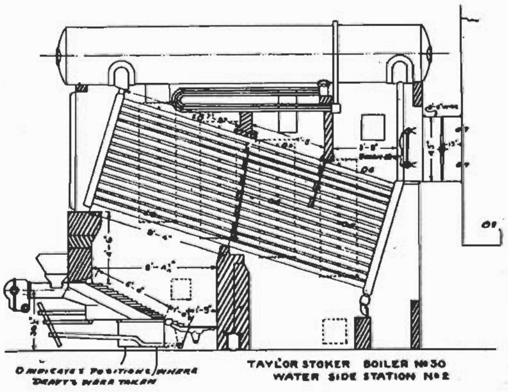


**Boilers at Delray Plant (above) of the DETROIT EDISON CO., installed in 1909, were Stirling Type "W", with 24,000 sq ft of heat surface over one fire. (Photo taken in 1911). This was a pioneer effort to adapt underfeed stokers to large boiler installations. Below: Completion of No. 2 boiler in the company's Conners Creek Plant, in 1914, was celebrated with a banquet held inside the unit.**

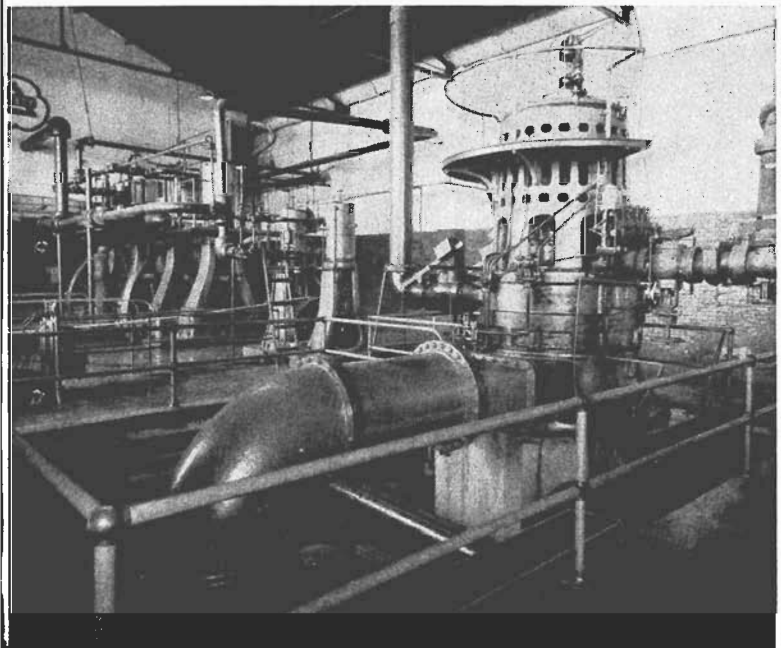


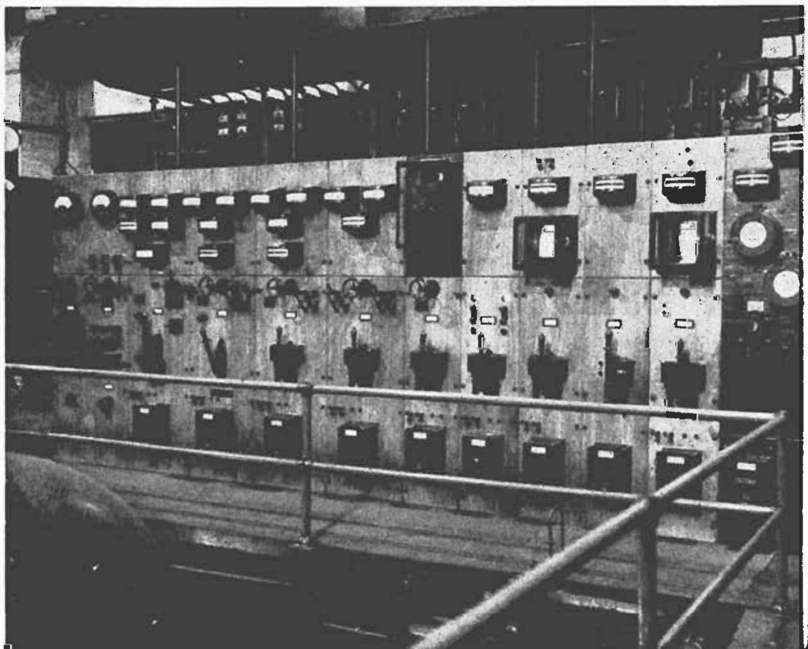
**1913. Lake Shore Plant of the CLEVELAND ELECTRIC ILLUMINATING CO. boasted of these vertical steam turbine units, the most modern then available. Vertical turbines reached their maximum size about this time because of steam flow and mechanical limitations. Constant efforts to improve system efficiency demanded continually larger generating units which could be met only with horizontal designs which enabled use of more adequate condensing equipment and permitted generator design to proceed unhampered by bearing and suspension problems.**

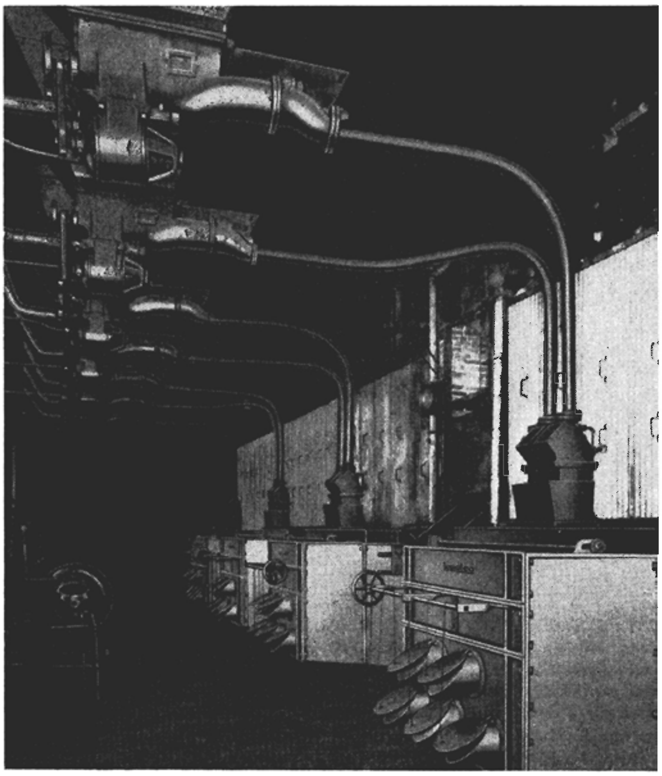
**1907. First underfeed stoker used in central station service, installed in CONSOLIDATED EDISON CO.'s Waterside Station, was significant as an early effort to mechanize boiler firing.**

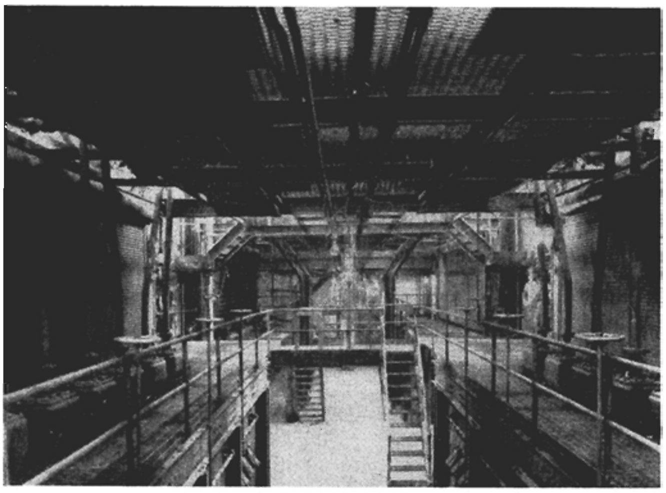

O INDICATES POSITIONS WHERE DRAFTS WERE TAKEN
TAYLOR STOKER BOILER No 30
WATER SIDE STATION No 2

**1912. This Grand Junction Plant of the PUBLIC SERVICE COMPANY OF COLORADO served the dual function of supplying both ice and electric power. The view (left) is of interest as showing clearly the steam connectors for a vertical turbine unit. Switchboard facilities at this time were a far cry from today's metal-clad gear, but a big improvement over earlier installations.**



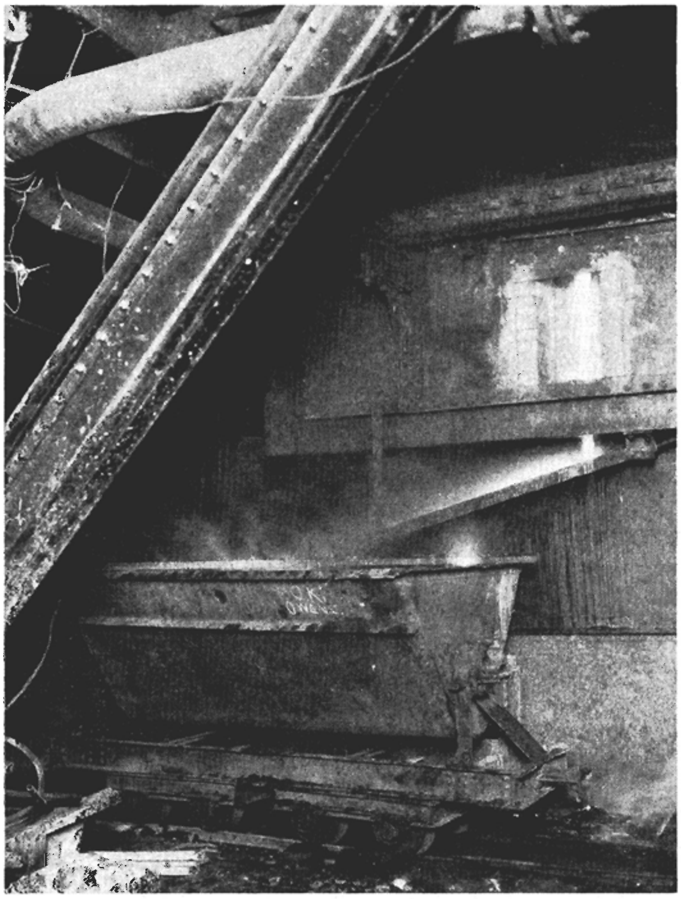


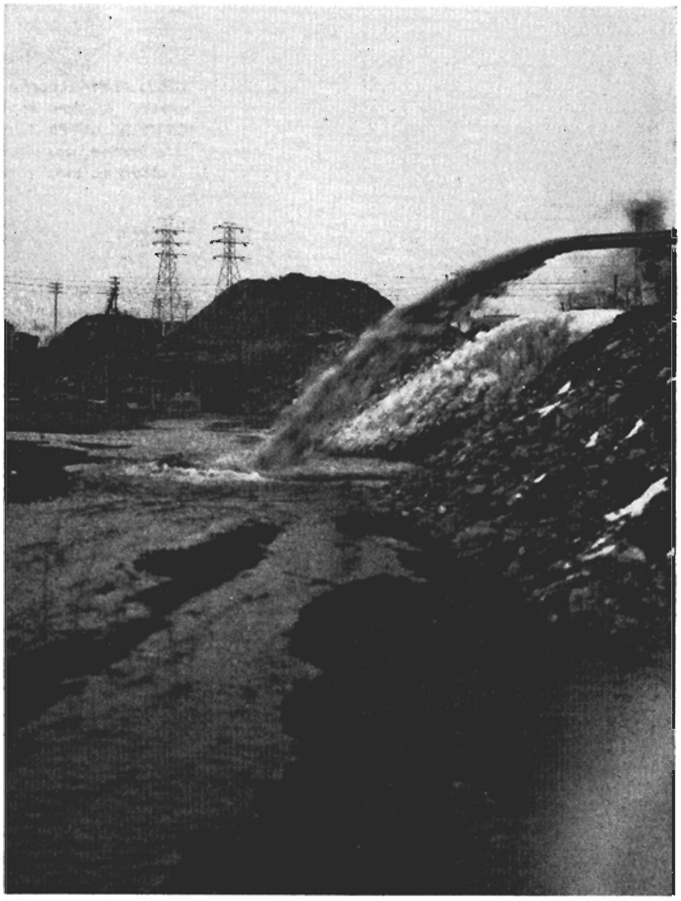




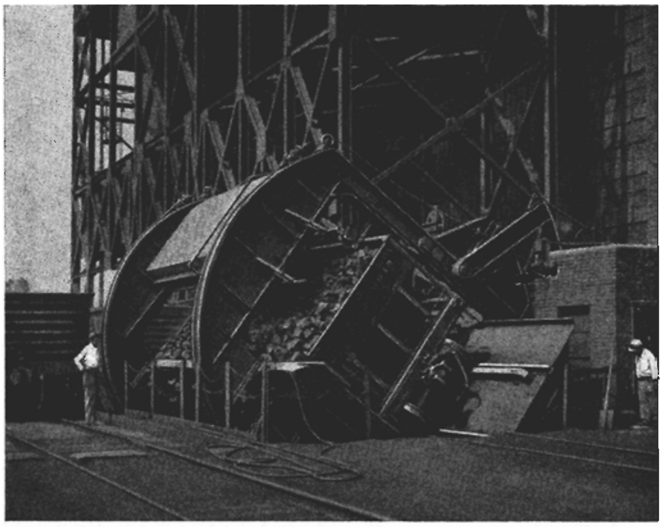
*(Combustion Engineering Co. photos)*

**1919. Left, pulverized coal burners and feeders in the original Oneida Street Station of the WISCONSIN ELECTRIC POWER CO., first pulverized coal application in the central station field. Pulverized fuel enabled higher plant efficiencies and paved the way for the great boiler capacities. Above, 1920—pulverized fuel installation in this company's Lakeside Plant. The pulverized coal burners are in back of the railings on either side of this firing aisle. Lakeside Station's improvement in efficiency between 1920 and 1930 is measured by a drop in Btu's required to generate a kilowatt hour from 21,000 to 13,500. Installation of radiant superheaters (1924), 1200 psi boilers with "topping turbines" (1926), use of a reheat cycle, and flue gas mill drying all contributed to this gain.**

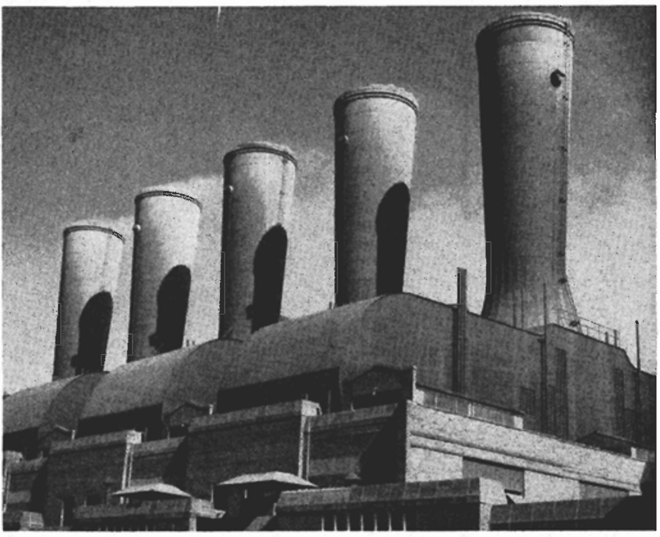




**1926. The evolution of the slag-tap furnace, first used at the Charles R. Huntley Station of the BUFFALO-NIAGARA ELECTRIC CORP., has played an important part in the development of the powdered-coal-fired furnace. Removal of molten slag from the furnace floor presented a real problem in pulverized coal installations. At the left is shown one of the original experiments in this plant when molten ash was tapped from the furnace into an ash car. Later, slag was tapped direct into a water jet sluicing system where it was chilled and disintegrated and then removed by pumps of special manganese steel, and a discharge pipe to convey the material to the disposal area (right).**



**Installation of this coal car dumper at the Cahokia Plant of the UNION ELECTRIC CO. in the early 1920's was indicative of the need to speed up coal handling to match the mass power production demanded by rapidly growing public acceptance of electric power.**



**1924. At its Trenton Channel Plant (above) the DETROIT EDISON CO. pioneered the use of Cottrell precipitators. By electrostatic removal of the dirt and ash from products of combustion, this development was a direct aid to good public relations.**

Further advances in metallurgy made both higher temperatures and higher speeds possible during the 1930's. While designers had long been aware of the efficiency gains possible from high temperature, high-pressure steam, the temperature ceiling had remained at 750 F from 1926 until the middle of the next decade. Since that time temperatures have been pushed steadily upward. In 1946, a 1,000 F, 1350 psi unit of 30,000 kw capacity was installed on the American Gas and Electric system at At-

*(Continued on page 219)*

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**1925. Construction view of the first water-cooled boiler furnaces to be installed in a utility station. They were placed in service at the Sherman Creek and Hellgate Stations of the CONSOLIDATED EDISON CO. OF N.Y., INC. Water walls, which cured refractory troubles, permitted still larger furnaces and higher furnace rates of operation.**

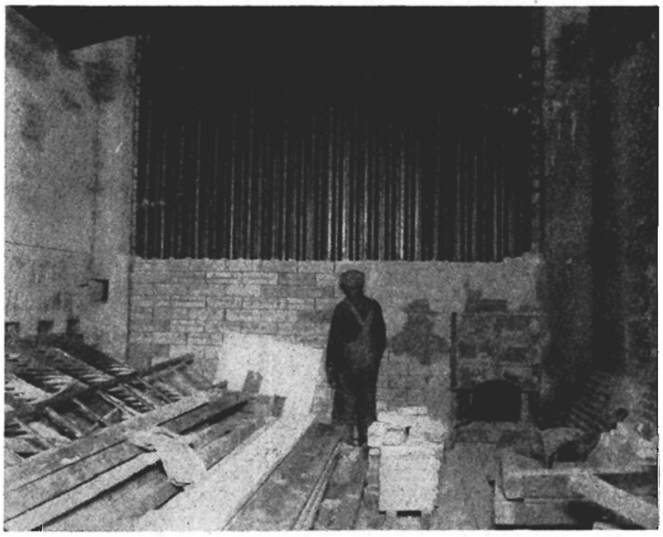
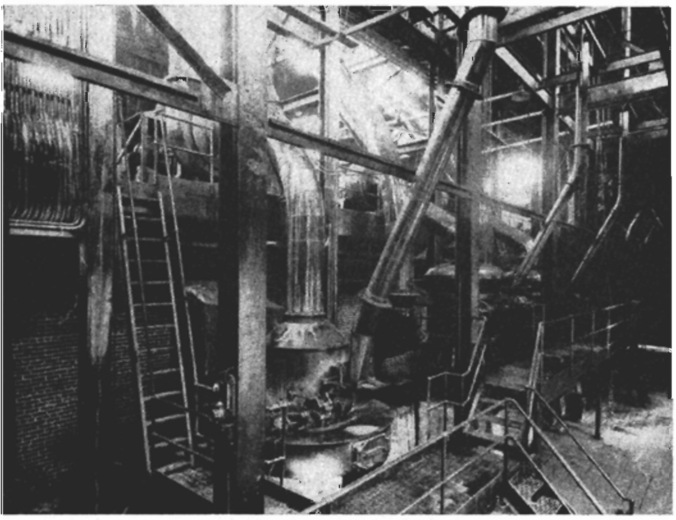
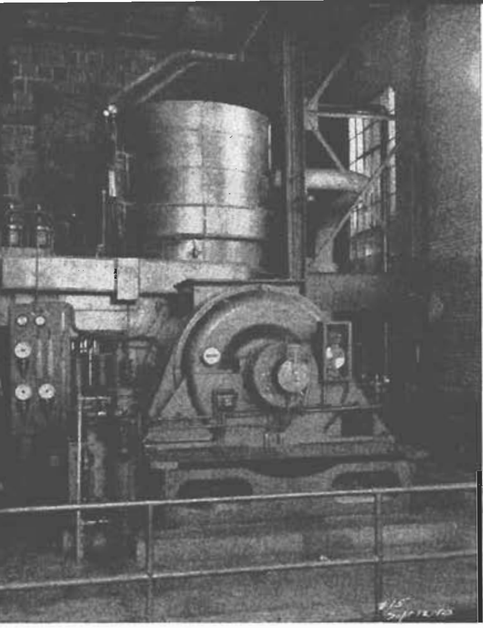


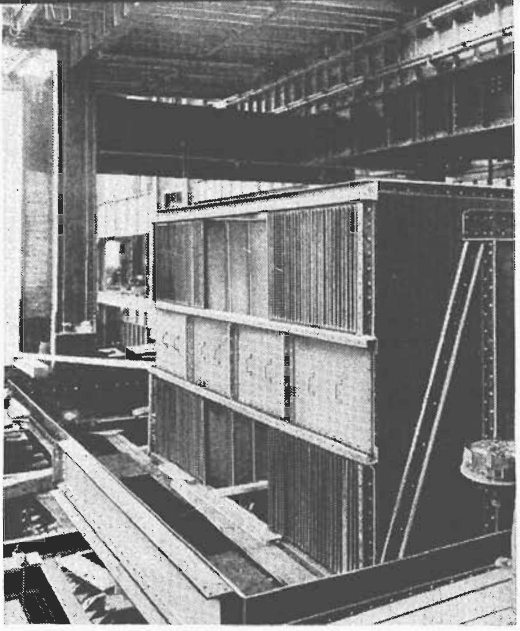
*Photo courtesy of Combustion Engineering Co.*

**1924 photographs, taken in the Middletown Power Station of the METROPOLITAN EDISON CO., show the pulverizing equipment layout (right) in the coal preparation plant, and the equipment (left) for handling the pulverized fuel direct from the pulverizing mills to the storage bins and the boilerhouse. Either anthracite or bituminous coal can be processed. All pulverized fuel is handled ina closed system, which eliminates dust. Mechanization of the fuel system from coal pile to boiler was a major step in the betterment of plant efficiency.**

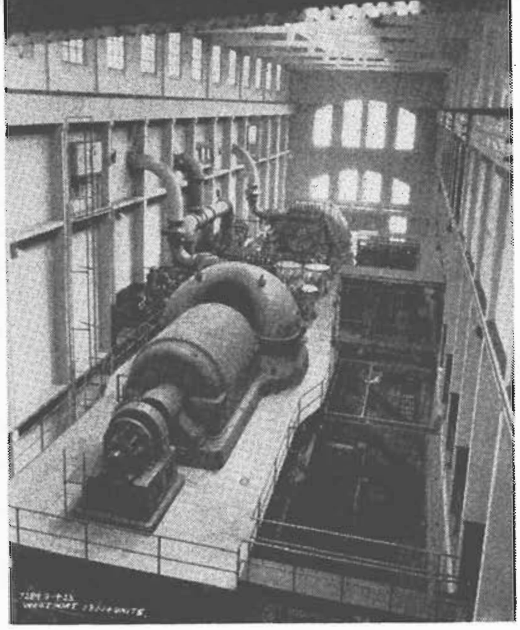




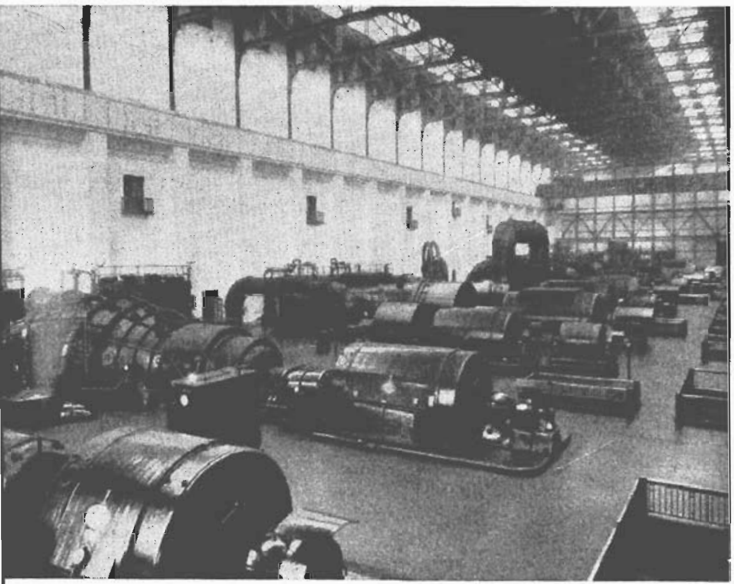
1923. The first mercury vapor turbine-driven generator, an 1800-kw experimental unit, on the **HARTFORD ELECTRIC LIGHT CO.**'s system. Operating economy of the mercury-steam cycle is attractive, but it has not been used extensively because of other factors.



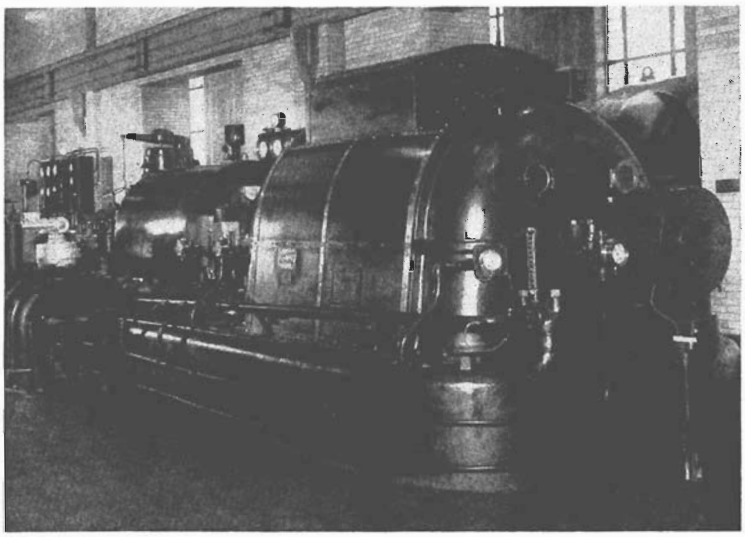
1924. Early installations of plate type air preheaters (shown here) by **DUQUESNE LIGHT CO.** and **KANSAS POWER AND LIGHT CO.** marked another step in utilizing waste heat to reduce the coal rate per kwhr.



1924. **CONSOLODATED GAS, ELECTRIC LIGHT AND POWER CO. OF BALTIMORE** drives its first "house" generator from the main generator shaft, a step to isolate station auxiliaries from system disturbances.

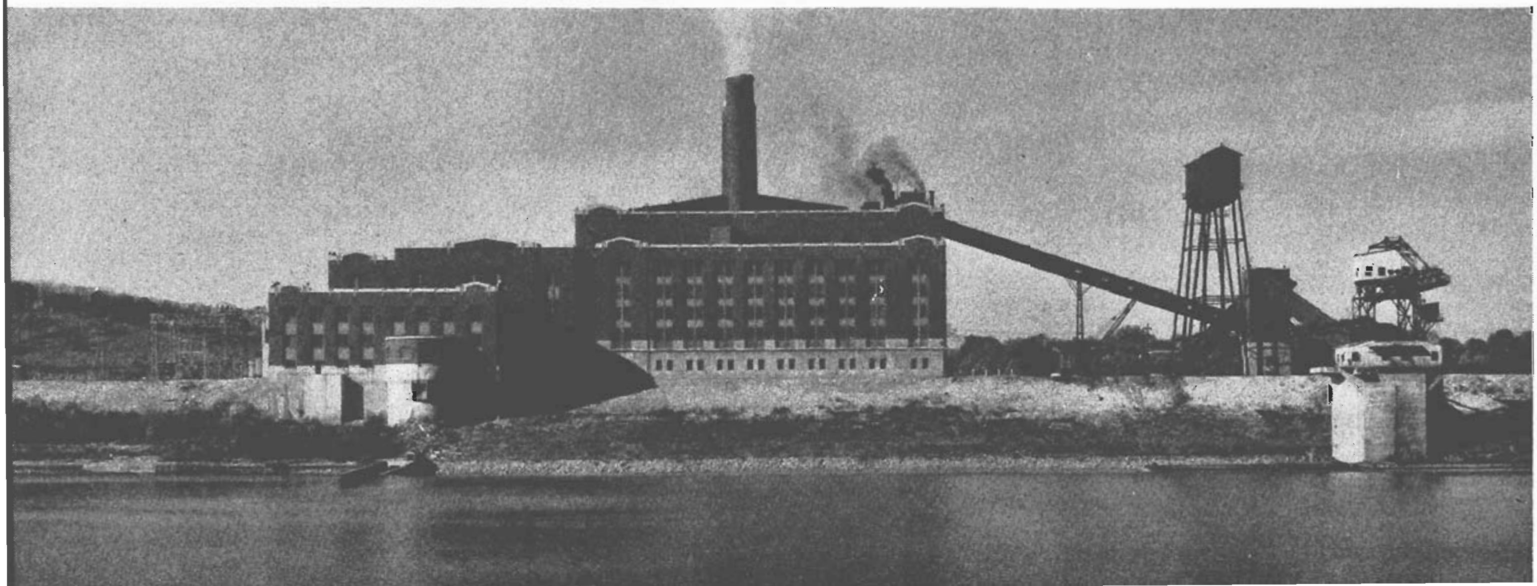


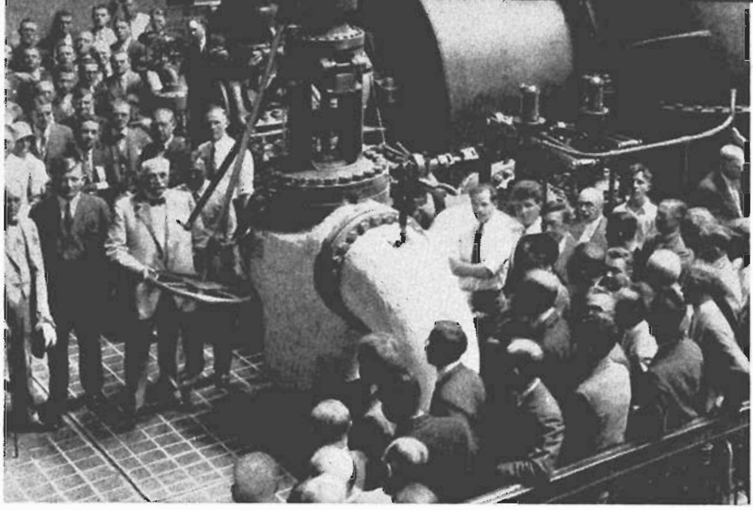
924. Early user of 600 psi, 750 F steam was **COMMONWEALTH EDISON CO.**'s rawford Station in Chicago. Adoption of 600-lb pressures made a significant improvement in unit efficiency.



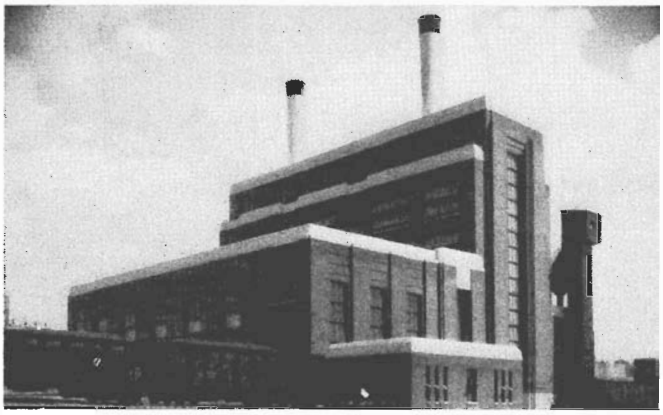
1925. First 1200-lb commercial installation of a "topping" unit, rated at 3150-kw, and installed in the Edgar Station of the **BOSTON EDISON CO.** Toppers exhausting into low pressure headers of older units, in effect save one set of boilers and permit over-all station economy to benefit from modern steam production facilities.

925. The Columbia Station (below) of the **CINCINNATI GAS AND ELECTRIC CO.** incorporated many of the latest developments of that period and achieved a record fficiency of 12,495 Btu's per kwhr generated. The boiler plant operated at 600 psig, 750 F, including a reheat cycle, and used pulverized fuel transported by compressed ir. This station was among the first to employ wagon scraper equipment in handling coal to and from storage, which equipment replaced fixed-type drag scraper equipment at this station in 1941. This coal handling method resulted in lower costs and permitted large expansion in storage pile areas.



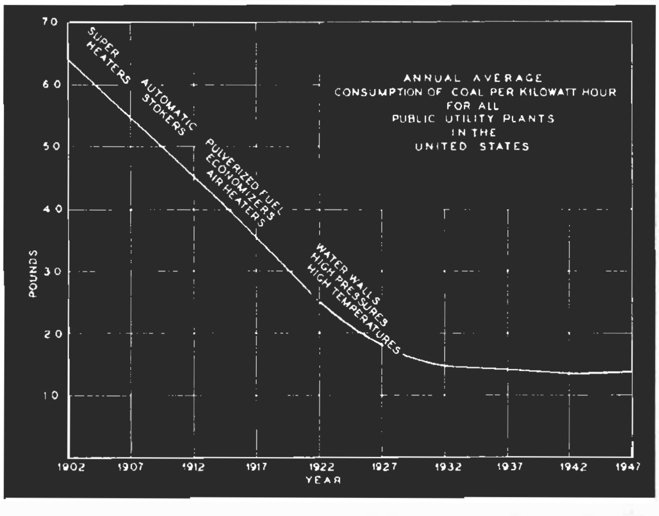


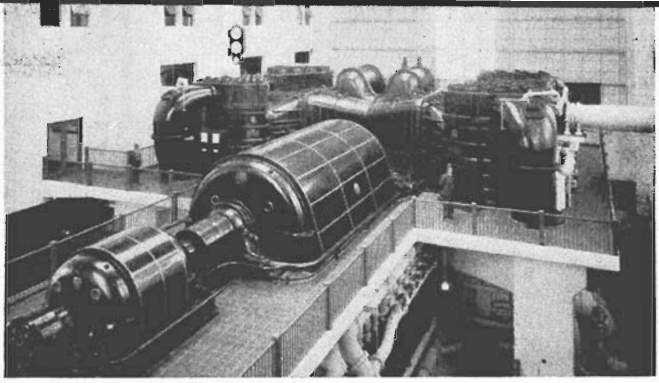
Taken in 1926, this picture shows Charles Francis Brush, scientist-inventor, as he turned the valve placing in operation a 35,000-kw turbine unit at the Avon Plant of the **CLEVELAND ELECTRIC ILLUMINATING CO.** Nearly 50 years earlier, in 1879, he threw the switch which energized the pioneer arc lighting system in downtown Cleveland.



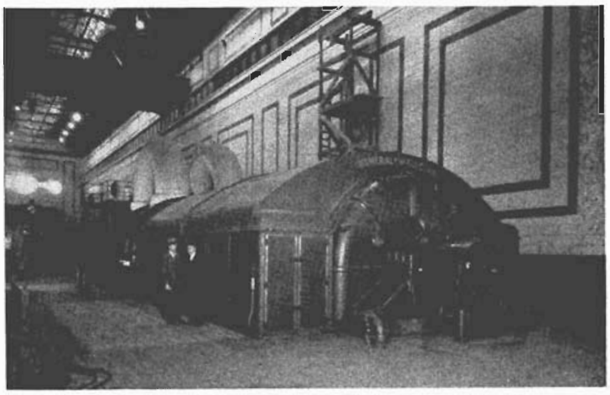
1931. Bremo Steam Station of **VIRGINIA ELECTRIC AND POWER CO.** was one of the first steam plants to be designed and operated at 825 F steam temperature. It featured single-pass boilers (among the largest built up to that time), high pressure, direct contact heaters and a diphenyl oxide system for recovery of heat in an economizer, which heat is transferred to air preheaters, and a 15,000 kw turbine unit, one of the first large 3600 rpm condensing units.

The decline in coal consumption per unit of power output, as shown here, has resulted from intensive engineering and development work. Radical innovations — new cycles employing reheat and regeneration — increased boiler efficiency— advances in temperature and pressure—better vacuum—generator refinements—automatic combustion control—all have contributed to this steam plant performance record. The attendant decreases in generating costs have been reflected in lowered consumer rates.



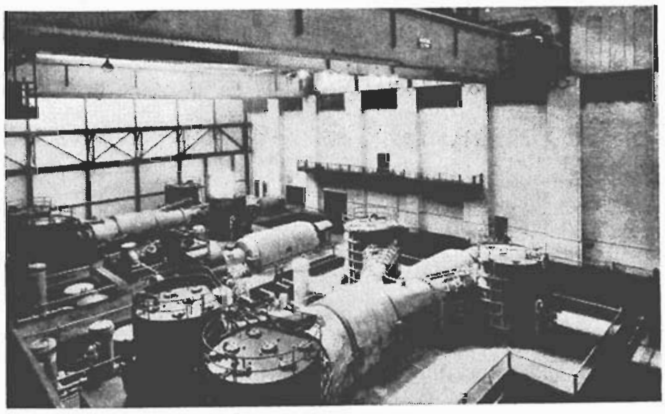


This 94,000 kw tandem-compound turbine generator unit, installed in 1928 at the Long Beach Station of the **SOUTHERN CALIFORNIA EDISON CO.**, marks the trend of the times toward the correlation of steam and hydro generating facilities for maximum system production efficiency and reliability.

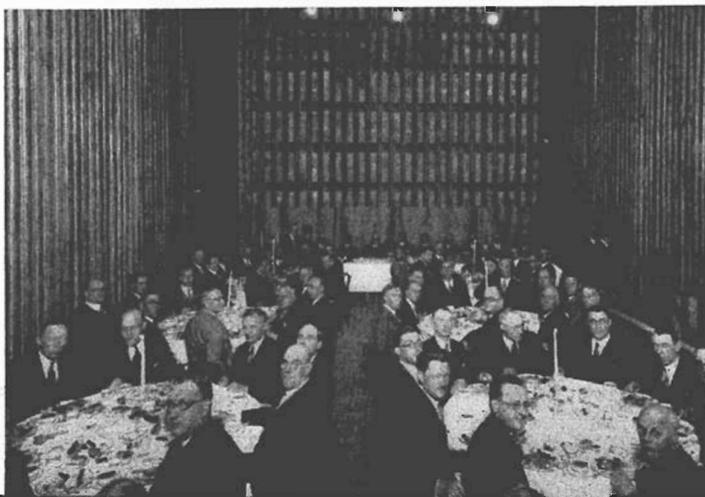


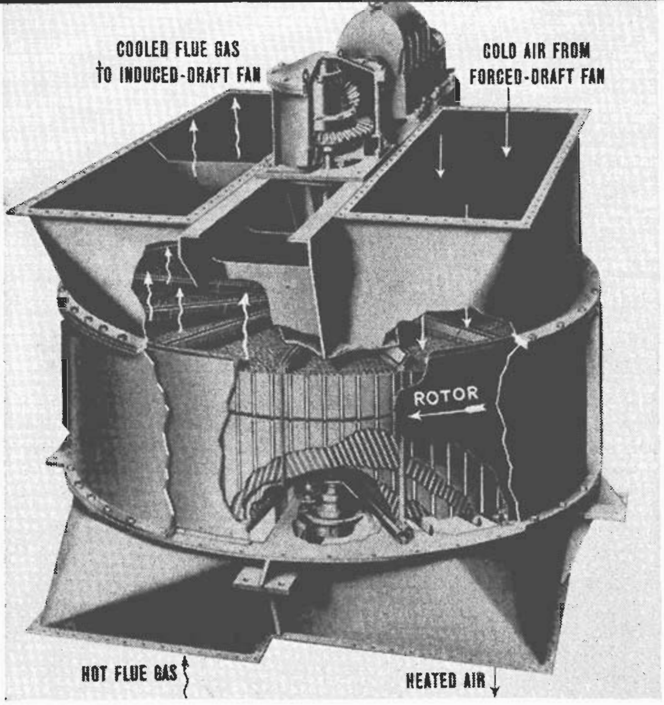
1929. This 160,000 kw, single shaft, double winding generator installed in the East River Station of **CONSOLIDATED EDISON CO. OF N.Y., INC.**, achieved a peak in designing large power capacity to fit into minimum floor space requirements.

1928. State Line Station of the **CHICAGO DISTRICT GENERATING CO.** has the distinction of housing the world's largest unit, a 208,000 kw, 3-unit turbine generator (a 76,000 kw high-pressure unit and two 62,000 kw low-pressure units). This installation highlights the progress toward use of large, economical steam units as intersystem power sources.

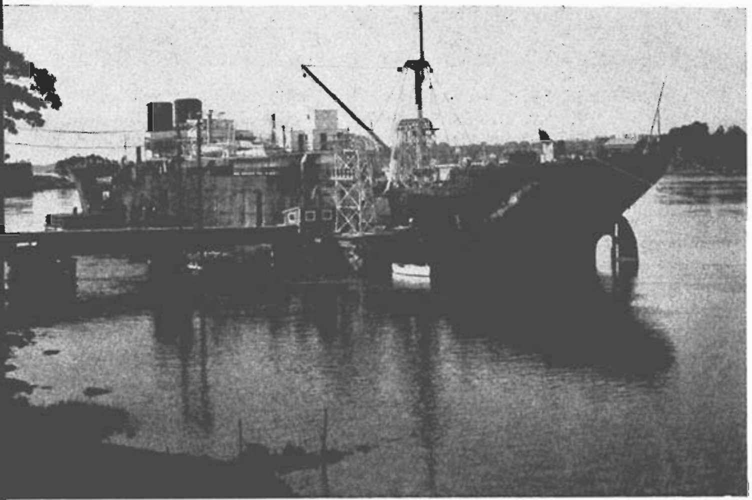


1929. This luncheon, held inside the firing chamber, celebrated the installation of the first million lb per hour boiler on the system of the **CONSOLIDATED EDISON CO. OF N. Y., INC.**



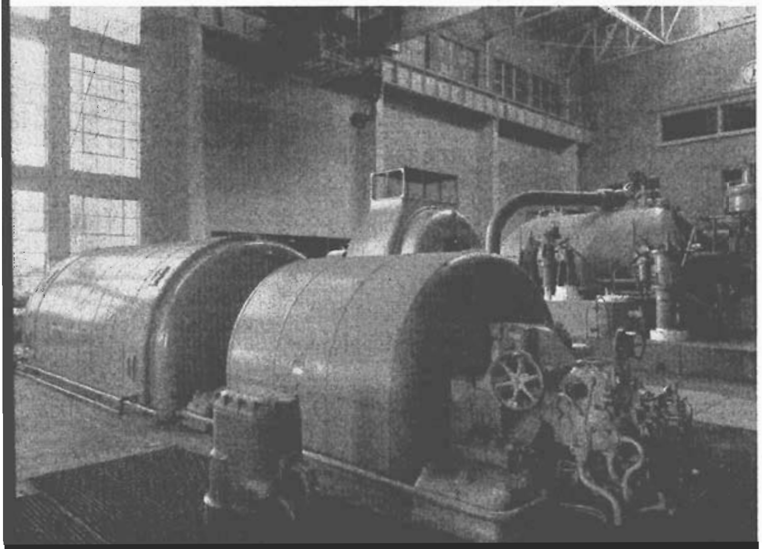

COOLED FLUE GAS TO INDUCED-DRAFT FAN
COLD AIR FROM FORCED-DRAFT FAN
ROTOR
HOT FLUE GAS
HEATED AIR

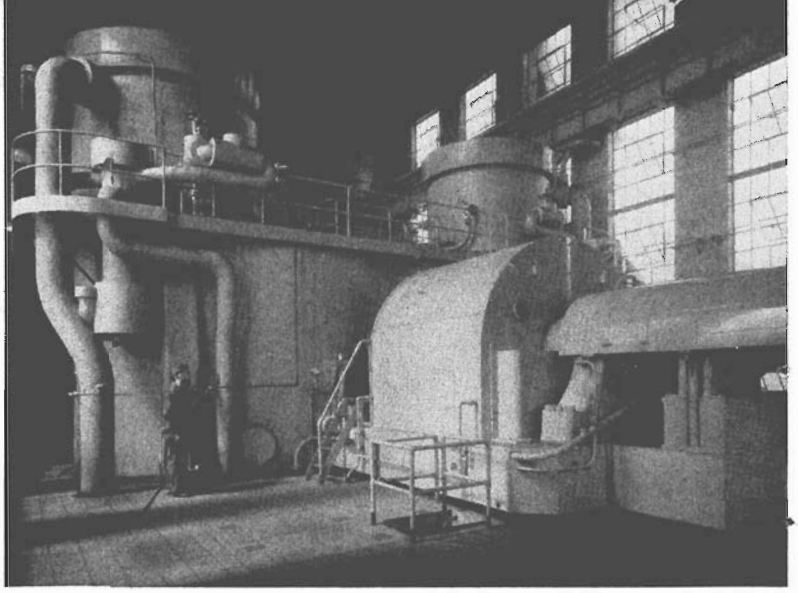
**1925.** Modern type of air preheater of the Ljungstrom type, cut away to show the principles of operation. By providing preheated air for combustion it makes possible higher over-all boiler plant efficiency with economically practicable first and maintenance costs. Photograph courtesy of the Air Preheater Corp.



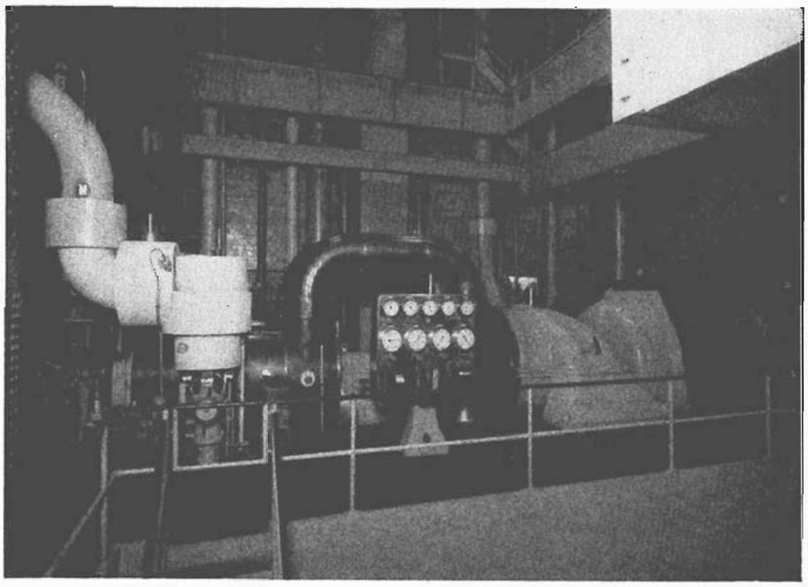
**1930. THE PUBLIC SERVICE CO. OF NEW HAMPSHIRE**'s 20,000 kw floating power plant, the JACONA, operated until 1945 when it was drafted for duty in the Pacific. A new 30,000 kw floater will replace the JACONA, portability being a valuable asset under emergency conditions.

**1932.** This 18,000 kw superposed unit, in the Burlington Station of the **PUBLIC SERVICE ELECTRIC AND GAS CO.**, was the largest 3600 rpm machine in operation for many years. Turbine designers, in producing high speed machines in larger capacities, contributed much toward economies both in performance and in physical size.



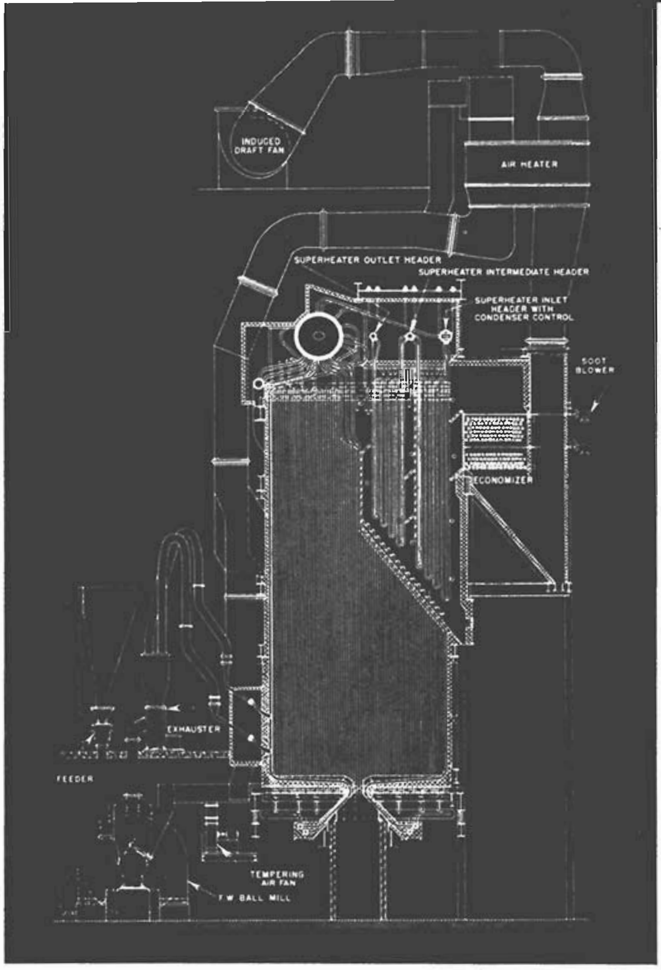


**1933.** This mercury turbine generator with condenser boilers at the Kearny Station of the **PUBLIC SERVICE ELECTRIC AND GAS CO.** (New Jersey) represents a type of equipment which can be superposed over steam plants of moderately high steam pressure to achieve renewed economic life of the plant, as steam conditions from this superposed unit are 375 psi and 750 F.



**1930. THE DETROIT EDISON CO.** explored the field of high temperature with this 10,000 kw turbine, made by the British Thomson-Houston Co. which used steam at more than 1,000 F. Experience thus gained laid the foundation for metallurgical advances which not only permitted further developments in efficient prime movers but also aided jet propulsion work so important for war purposes.

**1932.** Reliable field welding techniques for joints in piping encouraged the use of higher temperatures by eliminating flange connections, a source of trouble in early attempts to push temperatures and pressures to higher levels.


INDUCED DRAFT FAN
AIR HEATER
SUPERHEATER OUTLET HEADER
SUPERHEATER INTERMEDIATE HEADER
SUPERHEATER INLET HEADER WITH CONDENSER CONTROL
SOOT BLOWER
ECONOMIZER
EXHAUSTER
FEEDER
TEMPERING AIR FAN
F.W. BALL MILL

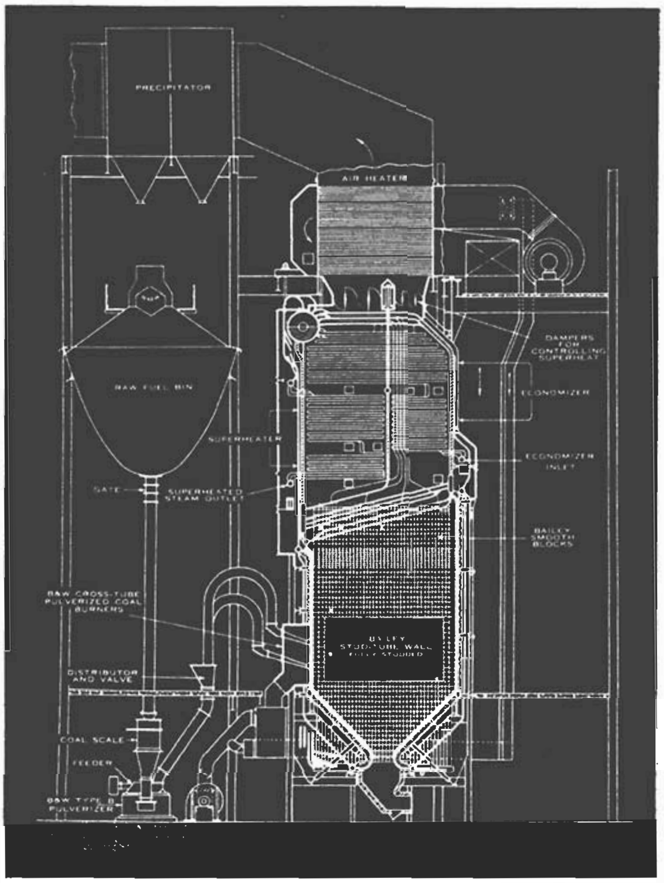
*Drawing courtesy of Foster Wheeler Corp.*

**Walnut Street Station of the COLUMBUS AND SOUTHERN OHIO ELECTRIC CO. utilizes this type of boiler. Steam capacity is 325,000 lbs per hr at a design pressure of 1500 psi and final steam temperature of 900 F. Due to the high operating pressure and high degree of super heat, this unit has no convection heating surface (boiler tubes) in the boiler proper. All steam is generated in the radiant waterwall tubes.**

lantic City. Its thermal performance is reported to be below 11,000 BTU's per kwhr.

Pressures, too, have been pushed upward, the highest in use for power generation being at the Twin Branch station on the AG&E system where 2,300 psi at 940 F steam conditions prevail.

**The basic elements of a present day high-head single-pass boiler are indicated in this sketch. This design takes advantage of economies inherent in high rates of heat release per ft of water-cooled furnace and the recovery of heat in flue gases. The superheater is located close to the furnace for maximum heat absorption necessary for economical operation at high steam temperatures. Economizers and air heaters add Btu's to boiler feed water and air for combustion respectively.**

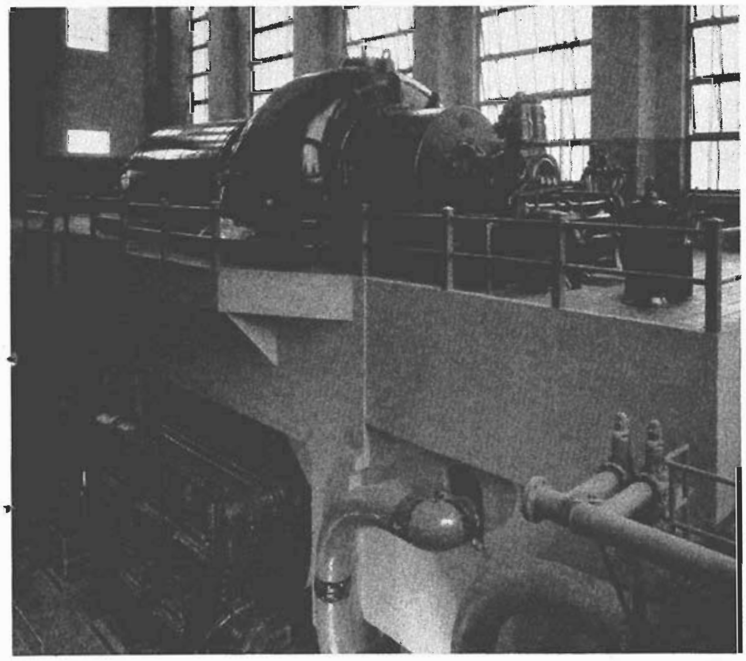


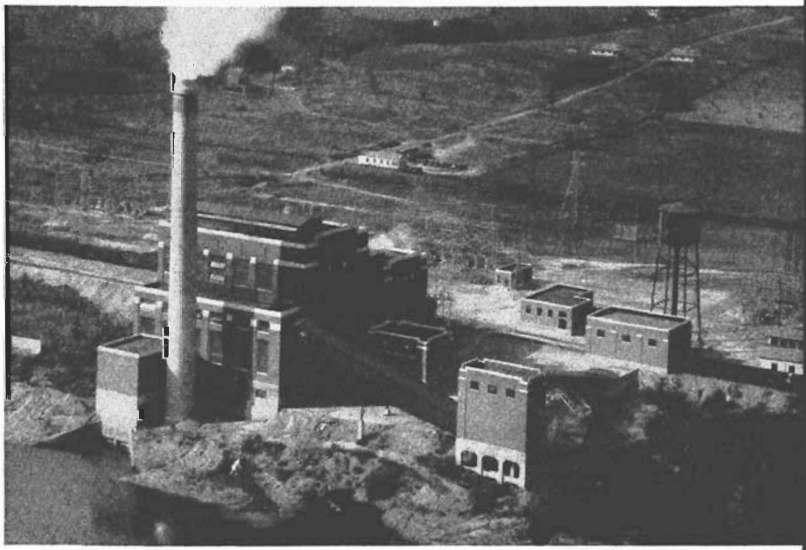
*Drawing courtesy of Babcock & Wilcox Co.*

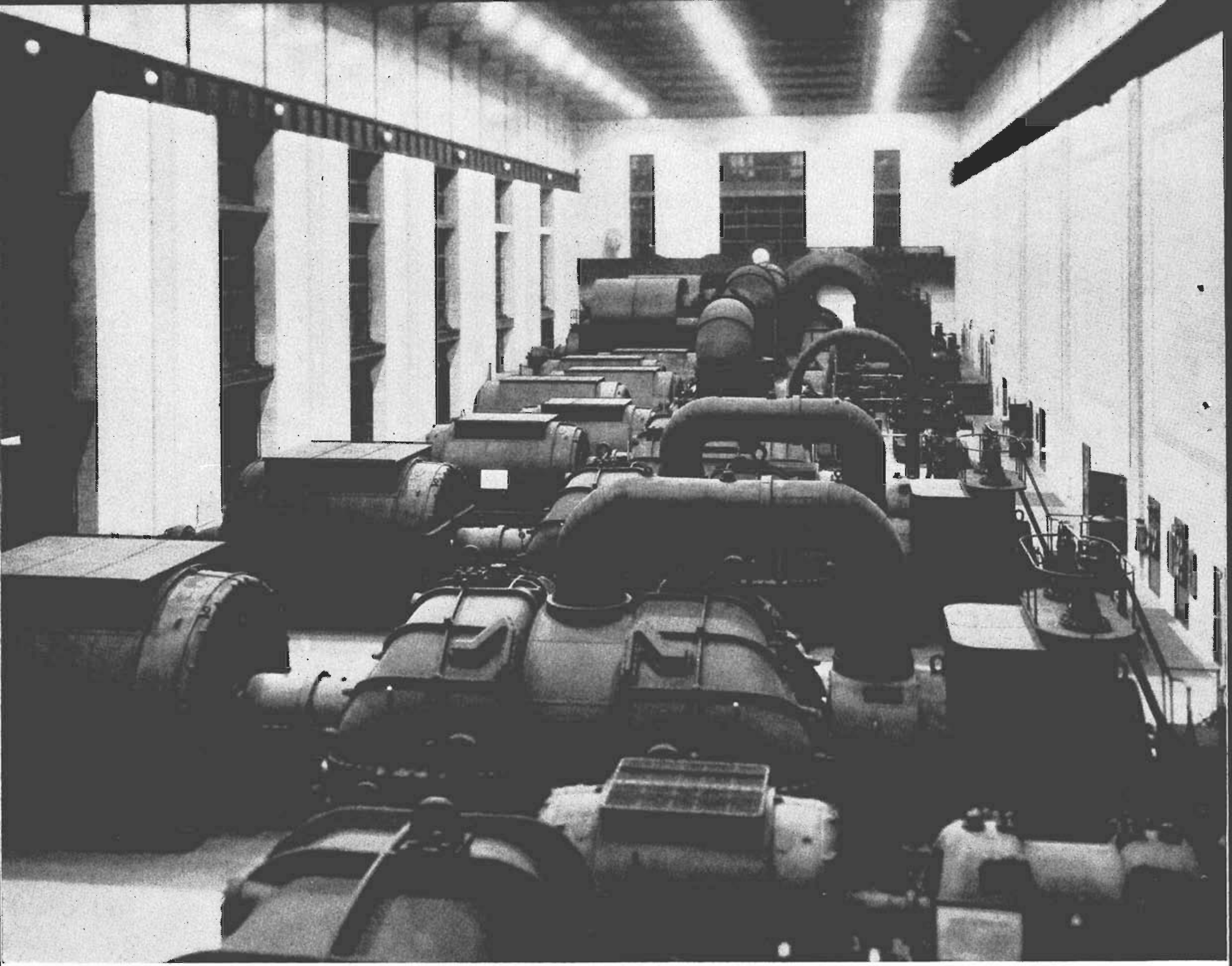
Hydrogen cooling for generating units marked another forward step in attaining further design economies. Hydrogen, as a cooling medium, enables rapid dissipation of the heat developed in the machine and permits the designer to increase the capacity

*(Continued on page 221)*

**1930. Gilbert Station of the NEW JERSEY POWER & LIGHT CO. (below, right), housing a 55,000 kw cross-compound turbo-generator unit, was one of the first stations designed for a 1350 psi boiler pressure and a 750° reheat for the 400 psi, 43,200 kw low pressure element (lower left).**

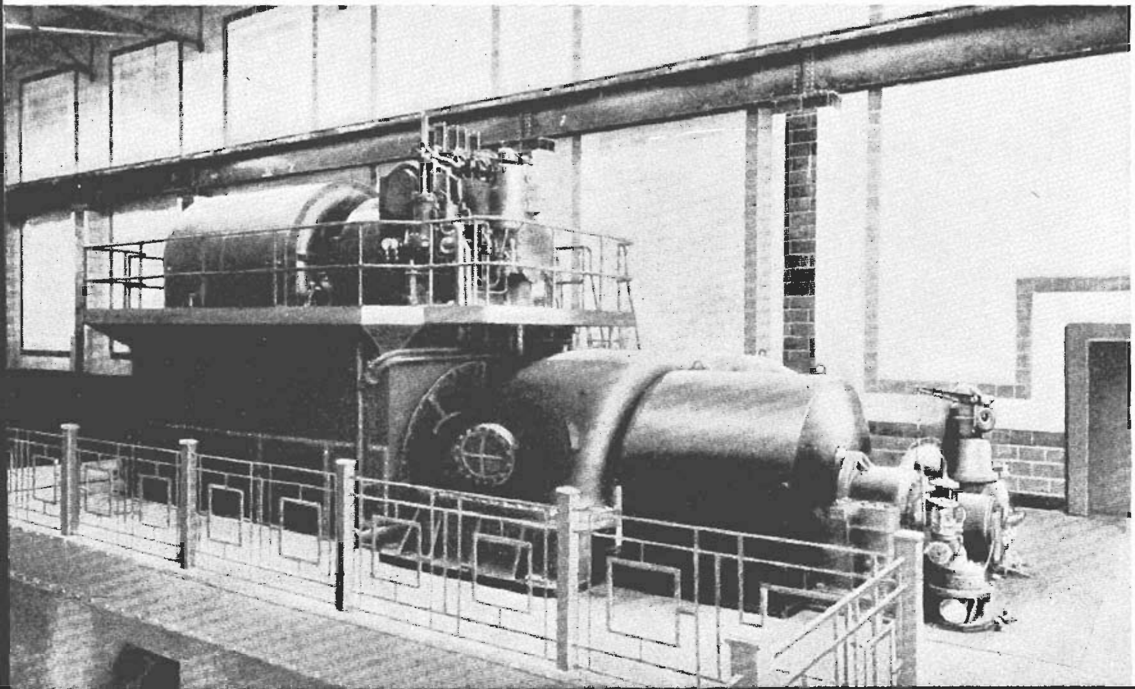






In 1932 this was the largest steam-electric central station in the world and it still holds that distinction. It is the Hudson Avenue Station of the **CONSOLIDATED EDISON CO. OF NEW YORK, INC.**, completed in 1932. Generating units shown here have a total capacity of 770,000 kw.

1931. The vertical compound turbo generator is another design which contributed to economy of floor space, with resultant savings in plant costs. This 25,000 kw unit was installed in the Perth Amboy Station of the **JERSEY CENTRAL POWER AND LIGHT CO.** High pressure element (top) operates at 1250 psi, 750 F with reheat on low pressure unit to 750 F.



The West Junction Steam Plant of the **HOUSTON LIGHTING AND POWER CO.**, is representative of the modern design of semi-outdoor type, which has materially reduced building costs. The semi-outdoor boiler is in the foreground. On the deck of the building, in the rear, is a 35,000 kw hydrogen cooled, turbine generator unit, housed under a removable cover. A duplicate unit is now being installed.

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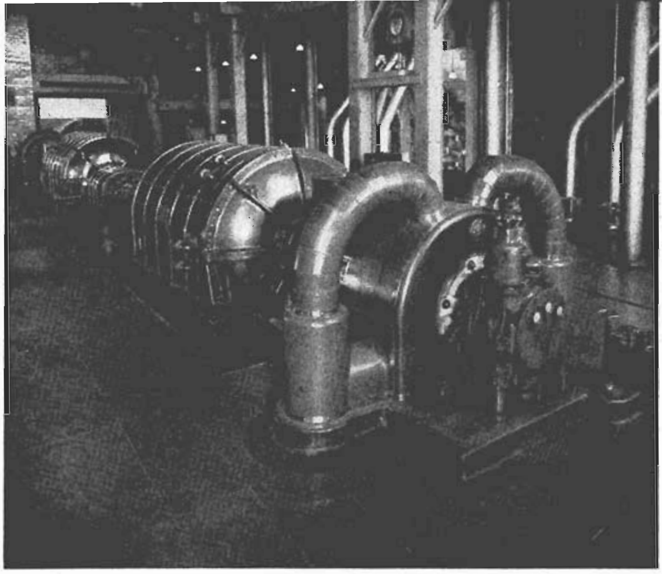
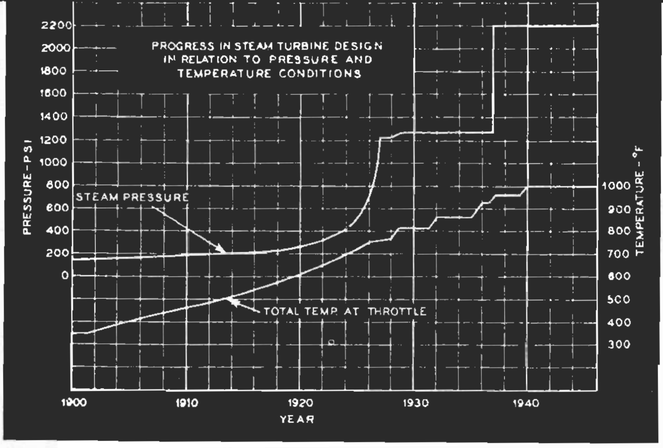


**1937. Rated at 30,000 kw, this topping unit installed on the system of the DAYTON POWER AND LIGHT CO., was the first hydrogen-cooled generator to be placed in commercial service. Sealing the generator in hydrogen permits reduction in generator friction and windage losses, permitting a design of smaller dimensions for a given capacity than would have been possible with an air-cooled machine.**

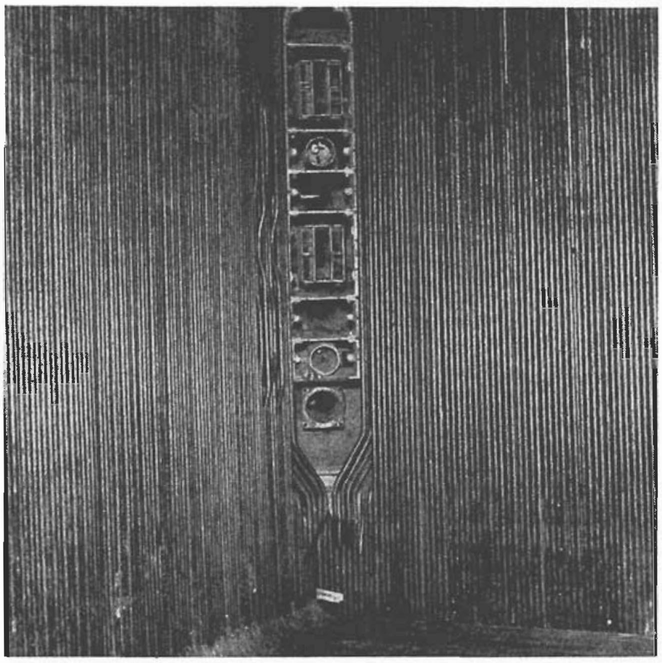
of a given frame size. At first hydrogen was utilized at pressures which were sufficiently above atmospheric pressure to ensure no leakage of air into the casing. More recently hydrogen has been used at higher pressures taking advantage of substantial additional economies in its heat dissipating properties.

Other refinements in station design have all contributed to better production performance. For example, early engineering provided for turbine drives of essential auxiliaries under the theory that the station steam supply was the most reliable source of driving power and was independent of system conditions. Later motor-driven auxiliaries were adopted with a house alternator driven from the shaft of the main generating unit so that as long as the main unit was running power would be available for station power needs. An alternate power supply of course would be the system itself.

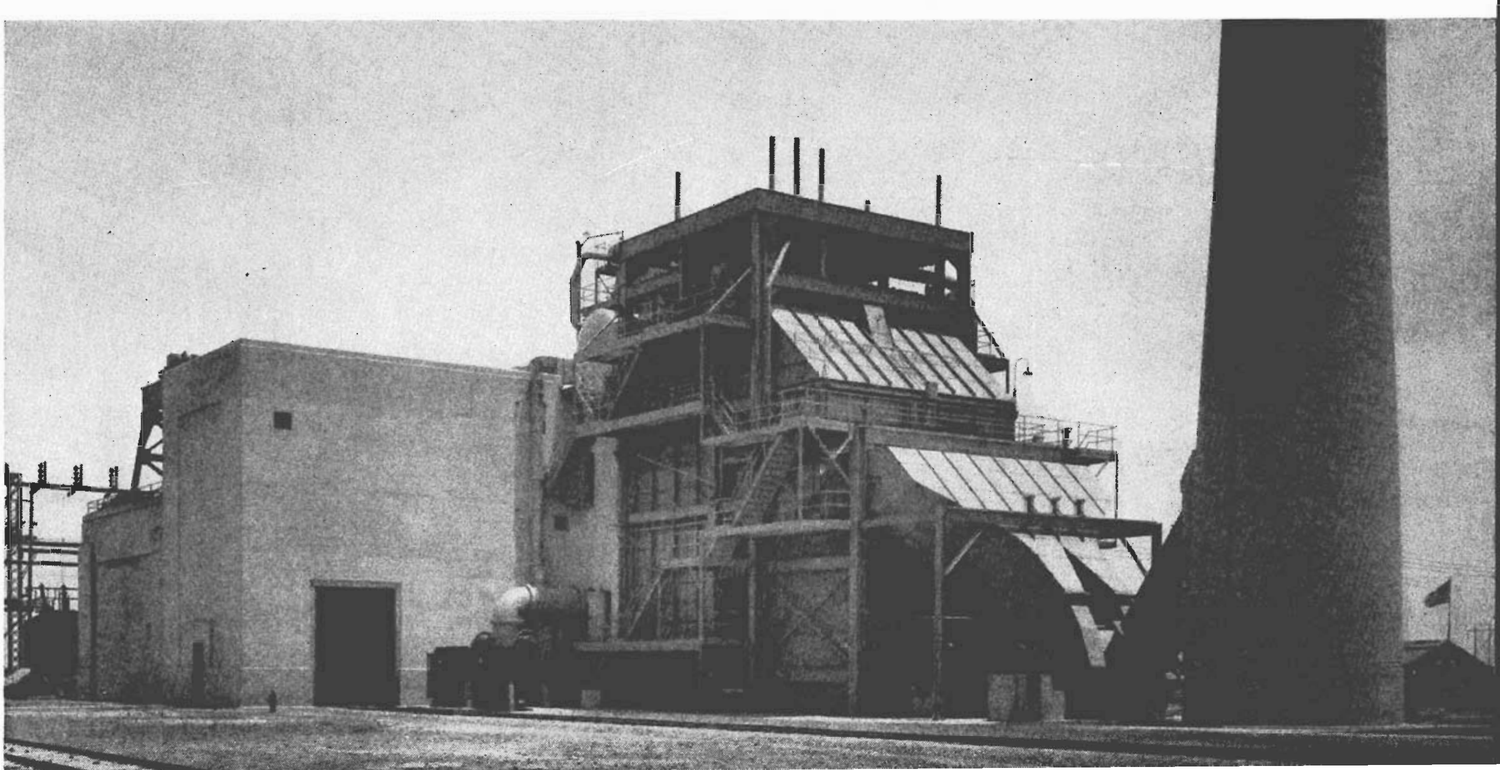
In so far as technology has permitted, design engineers have endeavored to foresee every possible contingency which would improve station reliability. Often the search for economy has contributed to this end, particularly as systems grew and the

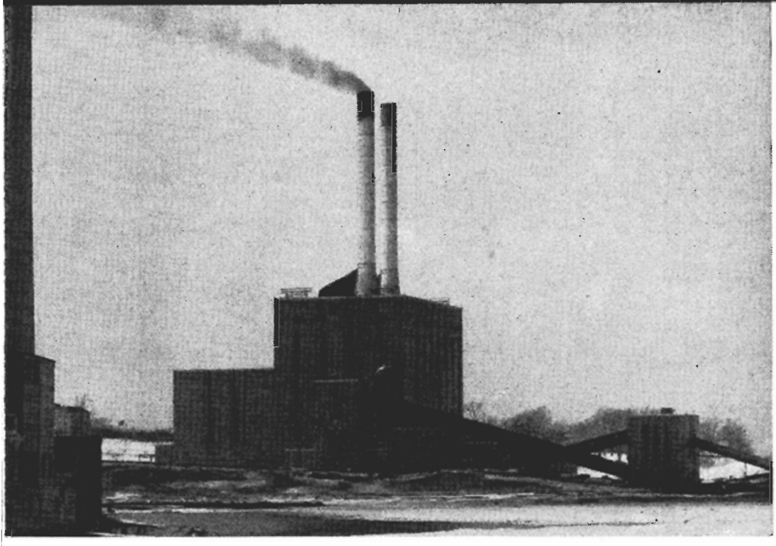


**Metallurgical developments, which made high temperature alloys available, plus advances in turbine design, have permitted utilization of increased steam pressures and temperatures as indicated in this chart, to achieve higher and higher prime-mover efficiencies.**

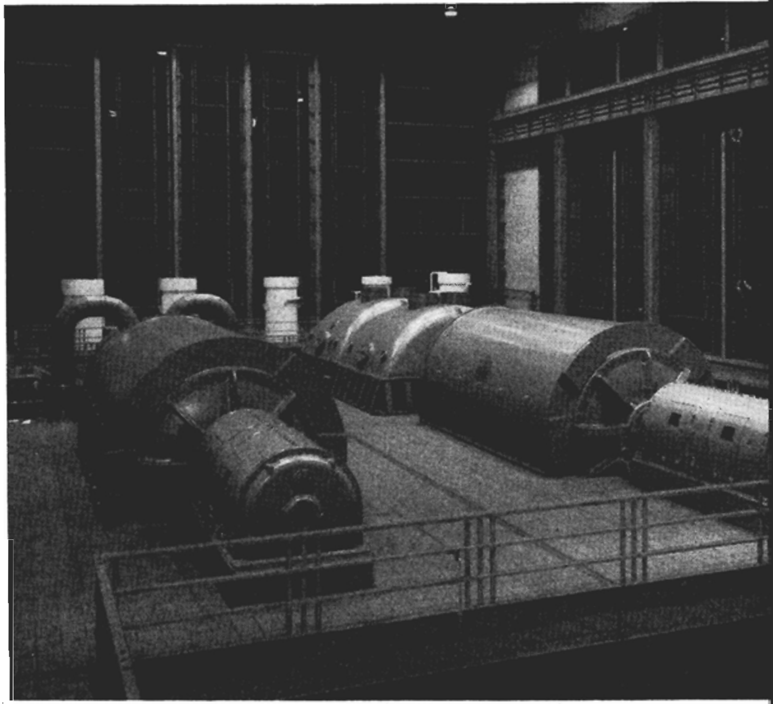


**Above. Interior view of the furnace of the forced circulation boiler, installed in 1942 at the Somerset Station of the MONTAUP ELECTRIC CO., shows one of the four tangential burners, located in each of the four corners. Furnace walls consist of closely spaced, small diameter tubing through which boiler water circulates under pressure. This unit is representative of the most advanced modern design of power station boiler.**





**1940. Oswego Steam Station of the CENTRAL NEW YORK POWER CORP., completed in 1940, houses two 80,000 kw turbo-generator units. Station design features unit construction, each turbine receiving steam from a single boiler with no cross connections. Considerable saving in piping and valves results, another step in conserving investment costs.**



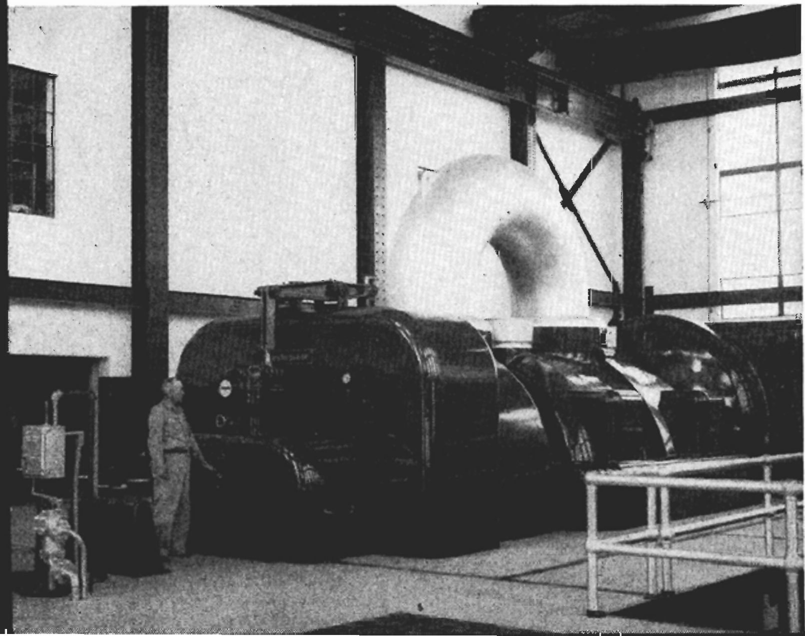
**1941. This cross compound design of a 100,000 kw unit for the Burlington Station of the PUBLIC SERVICE ELECTRIC AND GAS CO. (New Jersey) utilizes high pressure (1250 lb), high temperature (950 F) steam in the high pressure unit on the left, with cross-over pressure of approximately 100 psi, resulting in both high and low pressure elements each having a nominal rating of 50,000 kw. The hydrogen-cooled, 3600 rpm generators are duplicates and the complete high pressure unit itself is practically a duplicate of a 50,000 kw topping unit at another station on the system. Under ½ lb pressure of hydrogen the normal rating of the entire unit is 100,000 kw; under 15 lb hydrogen pressure the total rating of the unit is increased to 125,000 kw.**

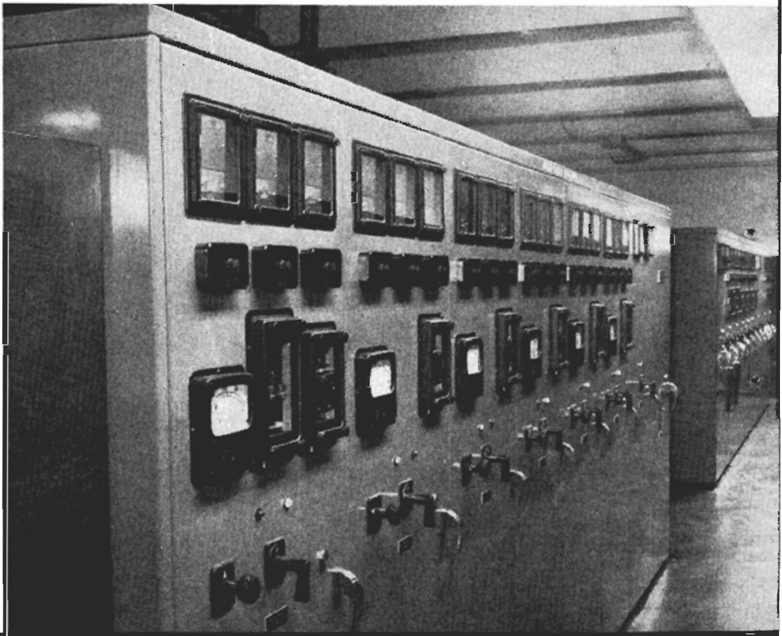
loss of any one generating unit did not represent a major catastrophe. As an example, many systems now consider the generator and its associated transformer bank as a unit and eliminate oil circuit breakers in the connection between the two. Other companies have substituted the air-blast circuit breaker for the oil breaker in the generator transformer circuits. Further economies in investment have been made by eliminating cross connections between boilers, a step made possible by the greatly improved boiler designs which make their availability almost equal to that of the turbine. Another trend is the complete isolation of each generator phase lead in its own enclosure within the station.

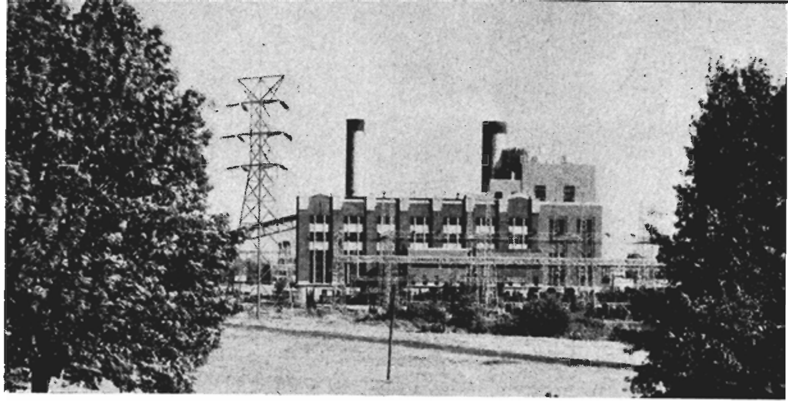
A glance at the thermal performance curve for the past 45 years, shown on page 217, indicates that the future rate of improvement in thermal performance probably will be much lower than in the past two decades. Refinements in fuel economy can be obtained but have to be measured against the added investment cost involved. Station designers, in recent years, have striven for greater simplification both as an economy and reliability measure. "Unit" design, wherein each power source is a complete entity from boiler to high voltage bus, with no cross-connections on either the steam or electrical end, is growing in favor. Semi-outdoor construction also is being used to lower first costs and obtain certain other advantages. Engineers thus continue to pioneer toward reliability, better economy and conservation of investment, the same goals that have challenged the industry since 1882.

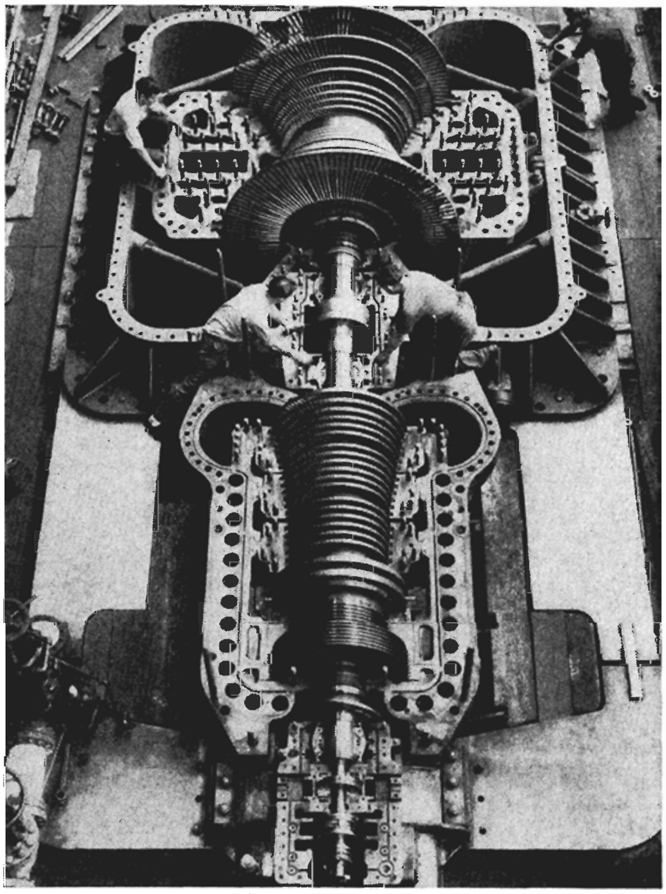
*(Continued on Page 225)*

**1941. (Below, left), This view of a 43,750 kva, 3600 rpm tandem compound turbo-generator unit installed on the GEORGIA POWER system illustrates the clean, compact design of modern prime movers. (Below, right), the metalclad cubicles for control of station power indicate that switch gear, too, has been streamlined since the early days of the industry.**

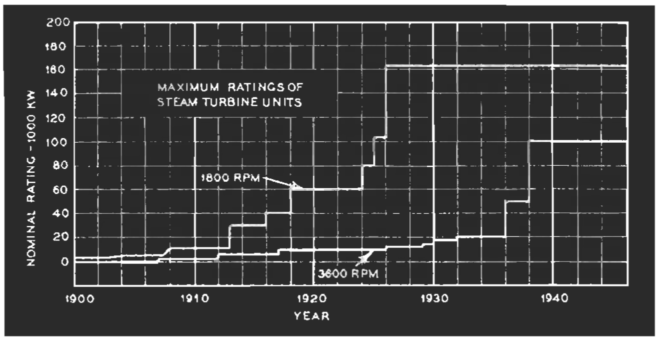




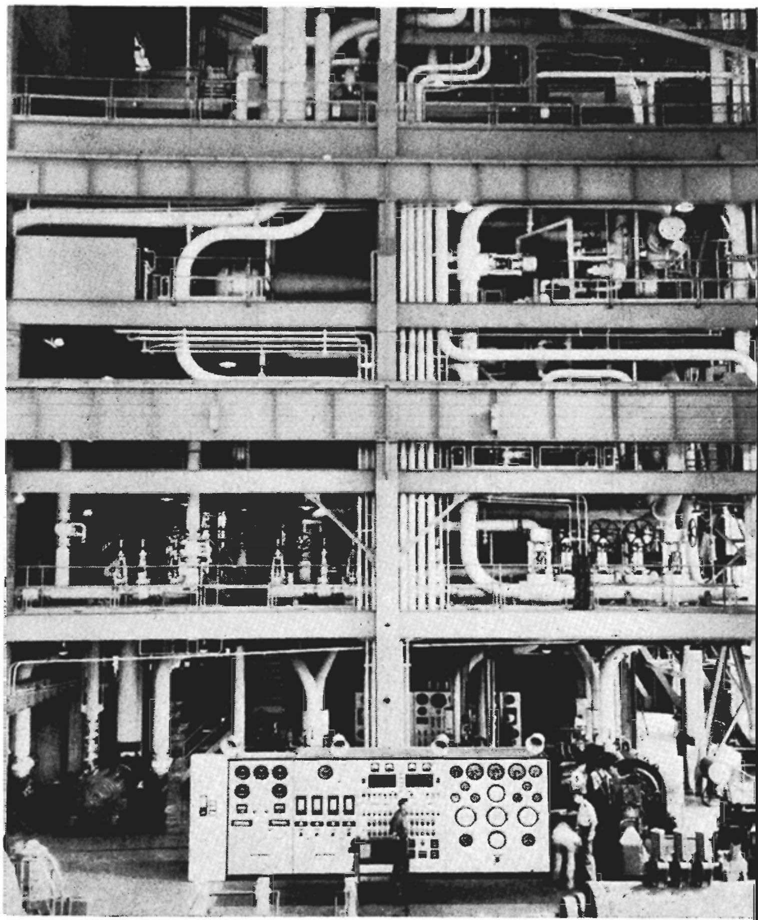




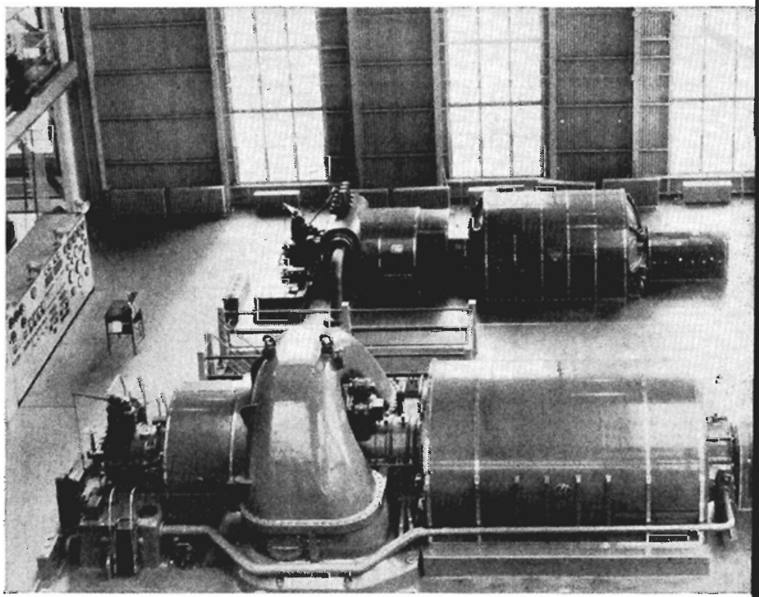
Interior of a 50,000 kw tandem compound turbo-generator which was installed shortly after Pearl Harbor in the Acme Station of the **TOLEDO EDISON CO.** In the foreground is the blading arrangement for the high pressure unit and in the rear the double flow low pressure element. Advances in metallurgy have made possible the design of compact, efficient turbines by giving designers metals which will withstand high pressures and high stresses. Tip speeds on these turbine blades will reach 850 miles per hour in normal operation.



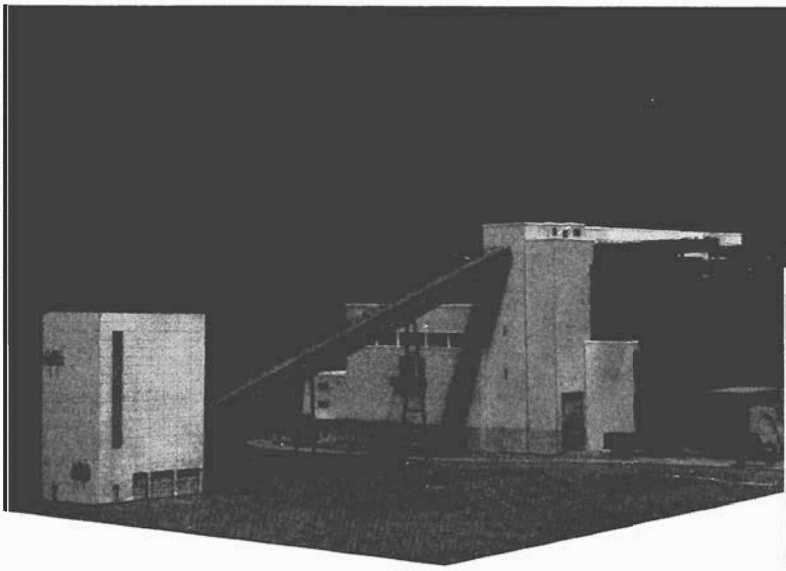
Improved mechanical design of steam turbines, and better materials, have made possible the increases in maximum single unit ratings shown on this chart. Larger unit ratings have contributed to increased individual plant efficiencies and permit efficient base load power production on a system-wide basis.



1941. Twin Branch (Ind.) Station (top, left) on the **AMERICAN GAS & ELECTRIC CO.**'s system offers visible proof of progress which has been made in efficient design. The extension at the right of the building houses the 2300 lb, high-temperature equipment which makes this station the highest pressure user in the central station field. The extension, about 1-3 as large as the original building, contains generating equipment with substantially the same total capacity as is installed in the original building. (Above) Background for the control board at Twin Branch is a symphony of high pressure piping. Hundreds of feet of special alloy steel piping, especially designed to withstand the high pressure and temperatures, was all electrically welded where joints were required. (Below) This view of the Twin Branch high pressure cross-compound turbo-generator unit shows, in the background, the high pressure unit which operates at 2300 psi, 940 F, and drives a 22,500 kw, 3600 rpm generator. The low pressure unit in the foreground operates at 1800 rpm and takes steam after reheat to 900 F. Generator rating is 54,000 kw, making a total of 74,500 for the complete unit. Both generators are hydrogen cooled. This station marked a large forward step in the exploration of the economics of higher pressure by nearly doubling pressures then in use. Its thermal performance is reported to be just over 10,000 Btu's per kwhr.

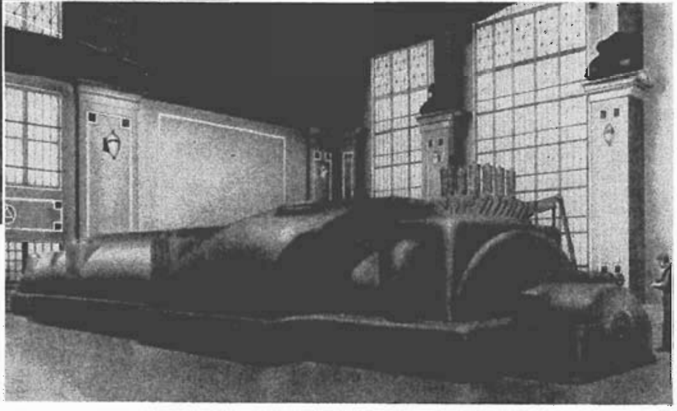


Large, modern stations which may use up to a trainload of coal in a day's operation, require large, but efficient fuel handling capacity. Coal storage piles formerly caught fire spontaneously under normal conditions. Modern practice employs caterpillar equipment to distribute and pack coal in storage. Today, mechanization of coal handling is practically complete, from car dump to boiler furnace, greatly reducing handling costs.

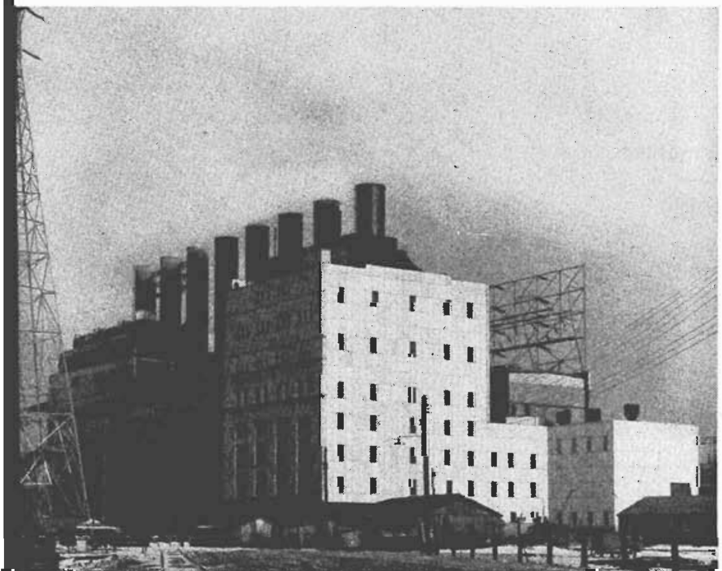


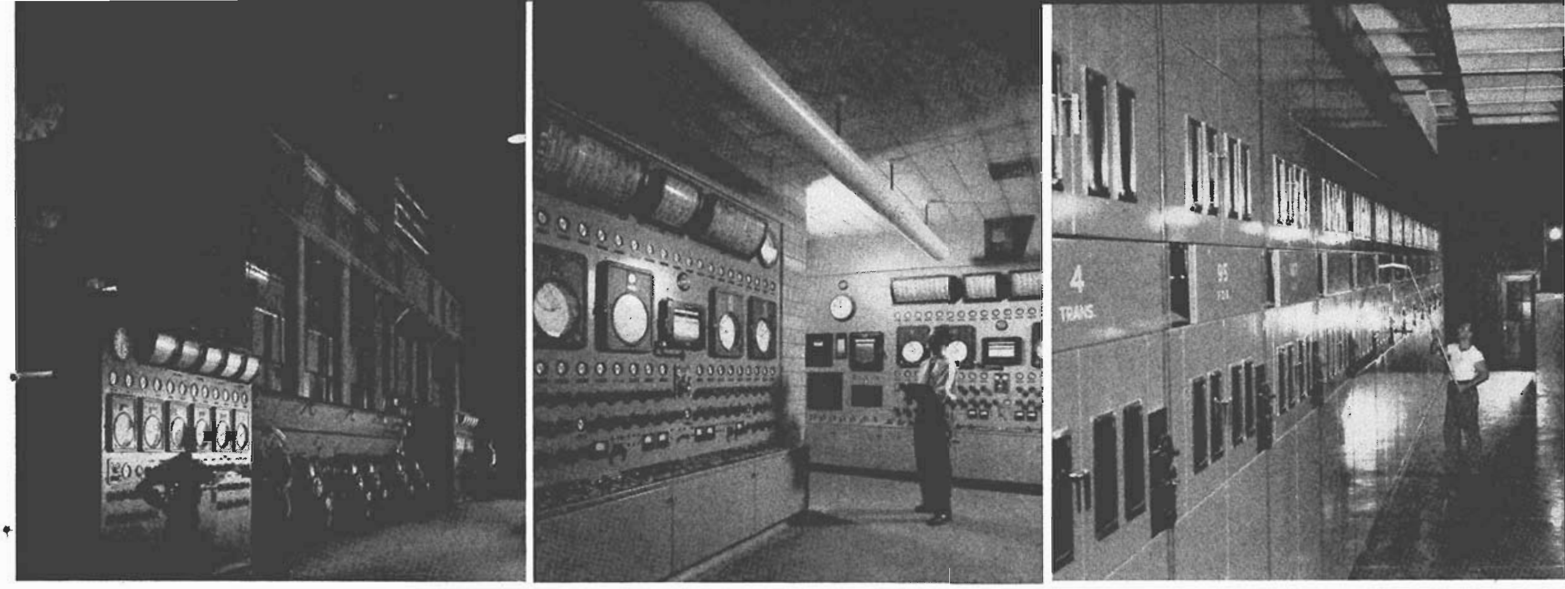
Model of Sewaren Station of the **PUBLIC SERVICE ELECTRIC AND GAS CO.** (New Jersey) shows semi-outdoor construction which combines lower investment cost with cleanliness and better ventilation. Part of the boiler and some of the auxiliaries are not enclosed. A unit arrangement is employed on the three main generators with no cross connections between the boiler, turbines and generator units. Improved boiler design increasing boiler availability to equal that of the turbine makes this possible.

(Below) This artist's sketch of the single shaft, 100,000 kw 3600 rpm turbo-generator for installation in 1947 in the Essex Station of the **PUBLIC SERVICE ELECTRIC AND GAS CO.** (New Jersey) illustrates the tremendous advances that have been made in plant design during the past 30 years. This unit with its boiler will occupy essentially the same area as a 22,500 kw unit which it replaces—more than four times the capacity in the same floor space.

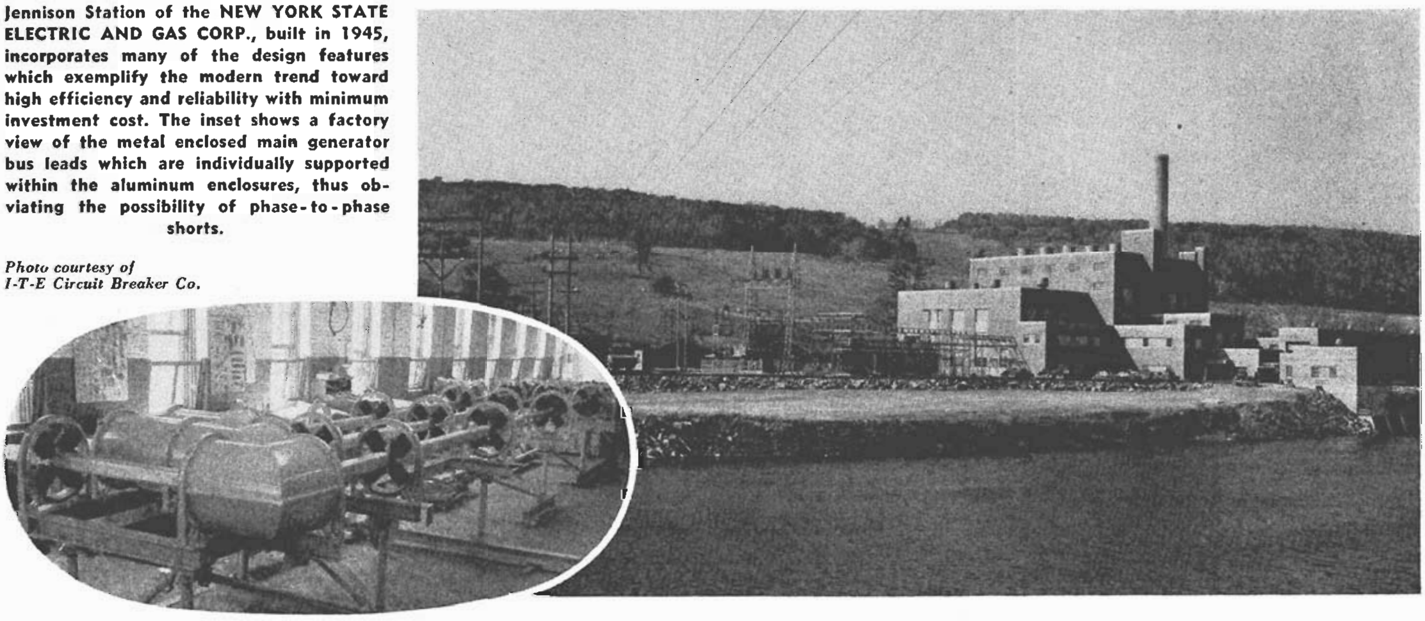


(Below, left) **WEST PENN POWER**'s Springdale No. 7 unit, housed in the station addition on the right, was completed shortly after V-J Day. This 80,000 kw plant addition, built under wartime conditions, produces a kilowatt-hour for well under one lb of coal and at an installed cost of approximately $100 per kilowatt. (below, right) Boiler feed pumps which force water into the boiler at 1840 psig. The motors used on these pumps require 1400 hp each, equivalent to about twice the total output of the Pearl Street Station in 1882.





**(Left, above) Combustion control equipment has reached the high state of perfection which insures maximum efficiency under all conditions of loading. This view of the boiler room of the James Reed Plant of the DUQUESNE LIGHT CO. shows the firing floor and control boards for stoker fired boilers. Note meter at left indicates station is carrying 105,000 kw. (center, above) Boiler control room showing the many instruments necessary to record and automatically control the countless operations necessary to coordinate the flow of coal, air and water to attain maximum boiler efficiency and to insure that the supply of steam will automatically and quickly follow changes in electric demand. (right, above) In modern power plant practice, every effort is made to eliminate not only mechanical failure but also any possibility of human error in station operation. These heavy duty, metal enclosed 13.2 kv. switchgear cubicles on the POTOMAC ELECTRIC POWER CO. system provide complete isolation between circuits on a double bus structure with 11 feeder positions plus a mechanical interlocking system which permits switch movement only in proper and correct sequence. Safety for the operators and the equipment plus protection against service outages, is thus assured.**

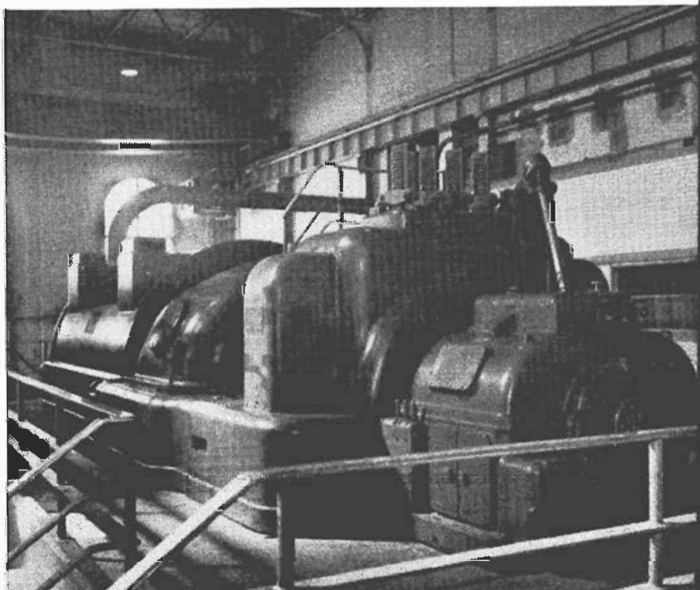


**Jennison Station of the NEW YORK STATE ELECTRIC AND GAS CORP., built in 1945, incorporates many of the design features which exemplify the modern trend toward high efficiency and reliability with minimum investment cost. The inset shows a factory view of the metal enclosed main generator bus leads which are individually supported within the aluminum enclosures, thus obviating the possibility of phase-to-phase shorts.**

*Photo courtesy of I-T-E Circuit Breaker Co.*

Future power production, as viewed at this time, likely will be subject to no radical change from present practices. On the horizon is the gas turbine in which the products of combustion are translated immediately into rotary motion rather than into energy in the form of steam. The economic possibilities of this development are obvious. However, the technological problems involved in developing and fabricating metals which will withstand the terrific temperatures for prolonged periods are many and the development of such units, particularly in the large sizes required for modern electric power production does not appear to be imminent. Still further in the future is the commercial applications of atomic power. As utilization of atomic energy is primarily a heat release phenomenon, it would appear that, if and when atomic power becomes available, it will have to be employed as a fuel substitute in plants large enough to warrant the heavy investment costs which will be necessary to make it safe. As yet there have been no reliable data upon which to base a sound analysis of the commercial practicability of using atomic energy. It therefore appears that steam plants, essentially in their present form, will dominate the power production field for some years to come.

**1946. Pioneer steam installation at 1,000 F. This 30,000 kw, 3,600 rpm turbo-generator unit is installed in the Missouri Avenue Plant of the ATLANTIC CITY ELECTRIC CO., part of the AMERICAN GAS & ELECTRIC system.**

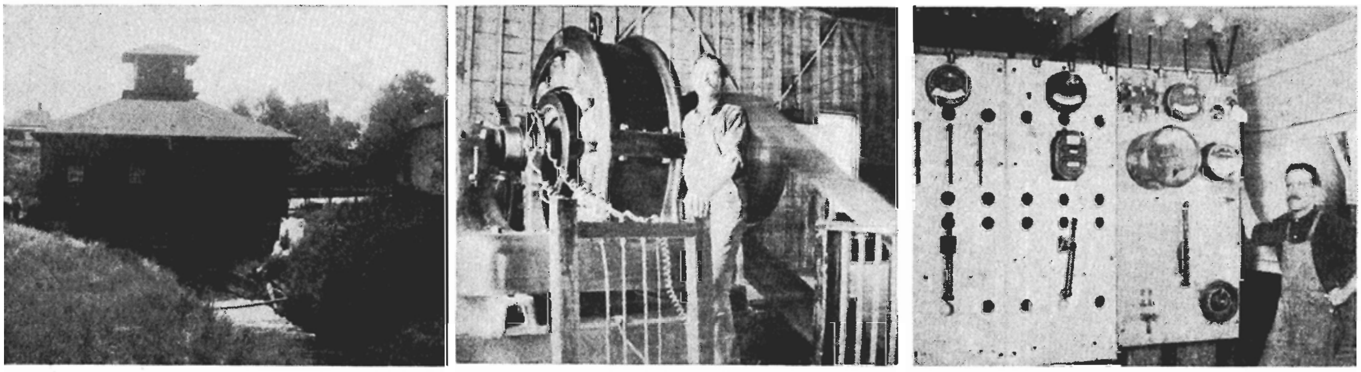


Yesterday's method of harnessing water power is typified by this ancient wooden water wheel which drove the first brass mill in the United States. Wood gearing on the far side of the wheel indicates how irrevocably industry was tied to water power sites in those days.

THE FIRST step in the more flexible utilization of hydro power came about when electric generators were geared or belted to the water wheels of the late 19th century. In the earliest plants power was utilized in the immediate locality for street lighting, plant and residential lighting, and factory drives. Later, as electrical demands increased, engineers began the study of various power streams, to determine what power sites were capable of economic development.

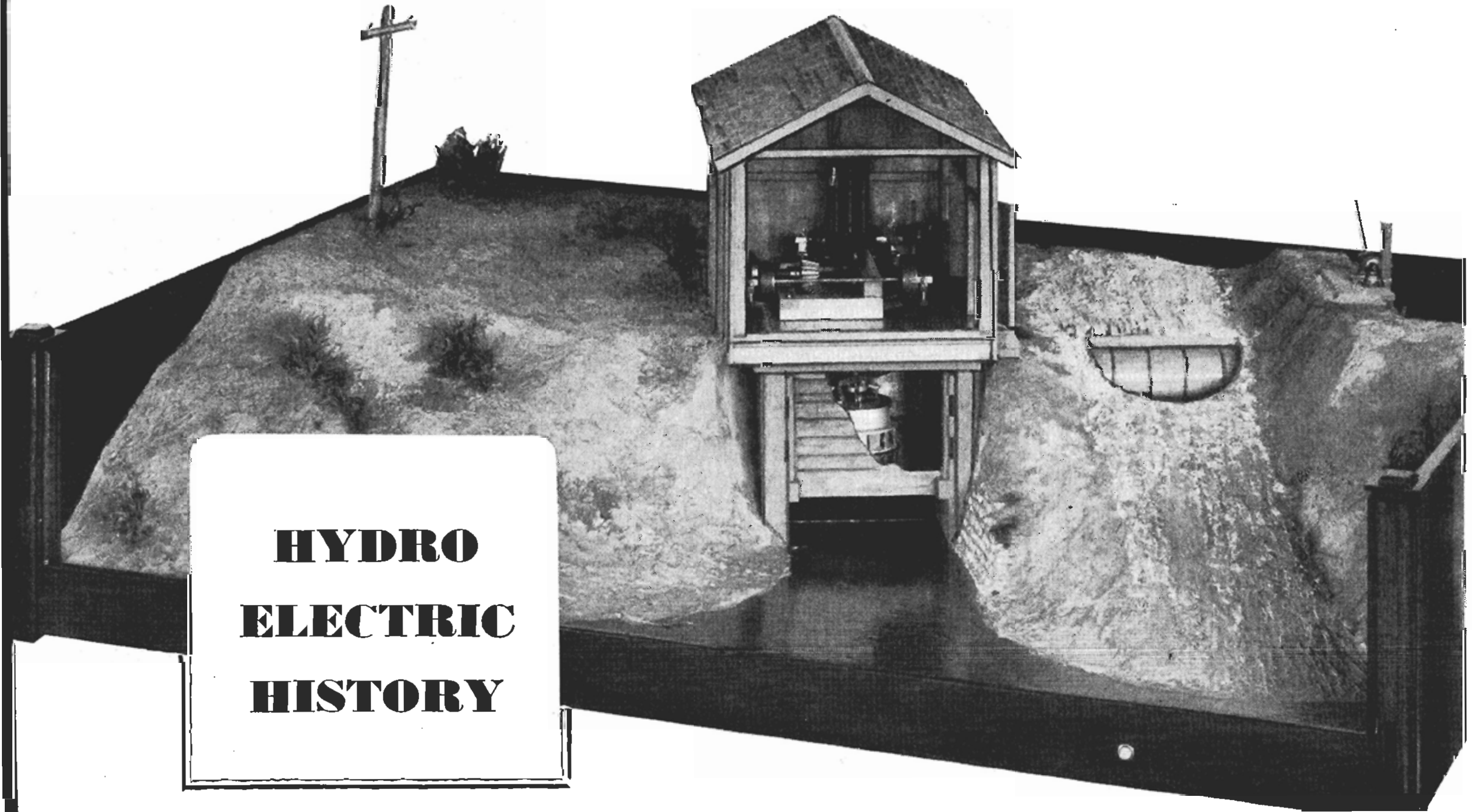
In the Rocky Mountain area and along the western seaboard the streams and riv-

*(Continued on page 228)*

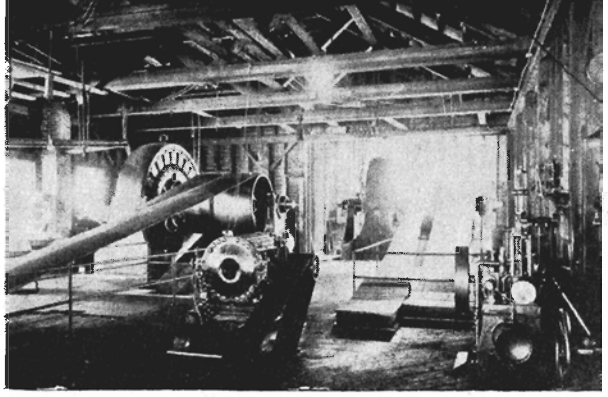


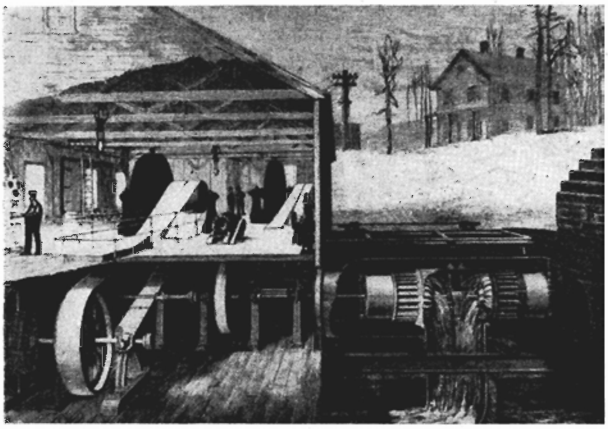
1886. Highgrove hydro-electric plant in Riverside County, Calif., supplied power for street lighting in Riverside. These three views show the exterior of the plant, the alternator and crude wiring system, and the switchboard.

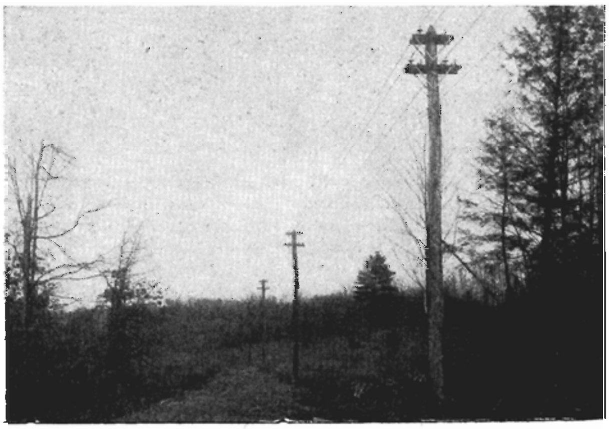
1882. Model of the first hydro electric central station, a fine example of early design showing arrangement of units and the old gear and pinion and belt drive to the d.c. generator at the rear of the upper floor. It initiated electric service (with two paper mills and one residence as customers) in Appleton, Wisc. and was the first plant on what is now the WISCONSIN-MICHIGAN POWER system. It was capable of lighting 250 sixteen candlepower lamps, for which a flat charge of approximately 33c per lamp per month was made.



# HYDRO ELECTRIC HISTORY

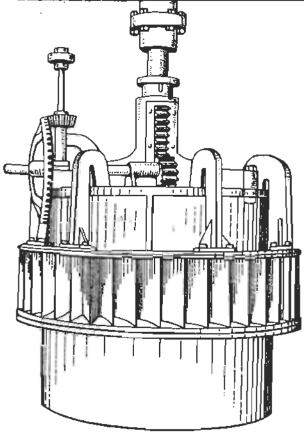




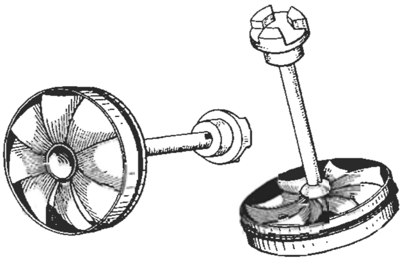


**1889.** Farmington River Power Station at Rainbow, Conn., where two 600 kw, 500 volt, 2-phase alternators and one small arc lamp were installed. Drawing shows a cut-away view of water wheels and shaft arrangement in this station. Plant output was utilized by the HARTFORD ELECTRIC LIGHT CO. from 1890 to 1916. The pole line shown above running between Hartford and an early hydro plant 11 miles away was the pioneer installation of aluminum wires (1899).

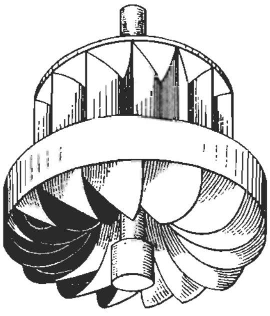
**1887.** Sixty years ago this hydro electric station was the only plant on the WASHINGTON WATER POWER system. It was located in what is now the center of Spokane and is symbolic of the part electric power has played in the development of the modern city.



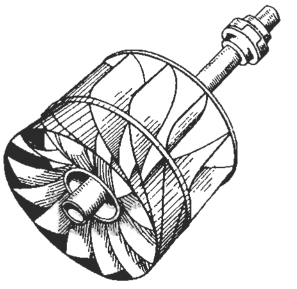
RISDON TURBINE



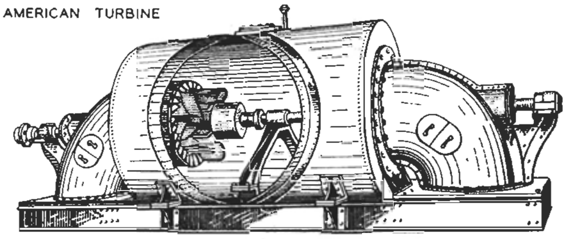
RUNNER OF CHASE TURBINE



RUNNER OF AMERICAN TURBINE



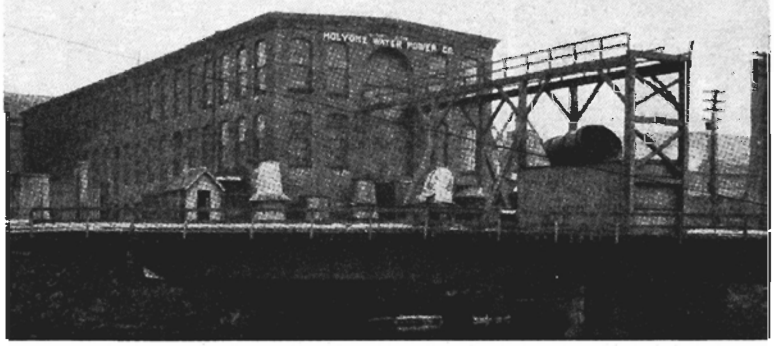
ALCOTT RUNNER

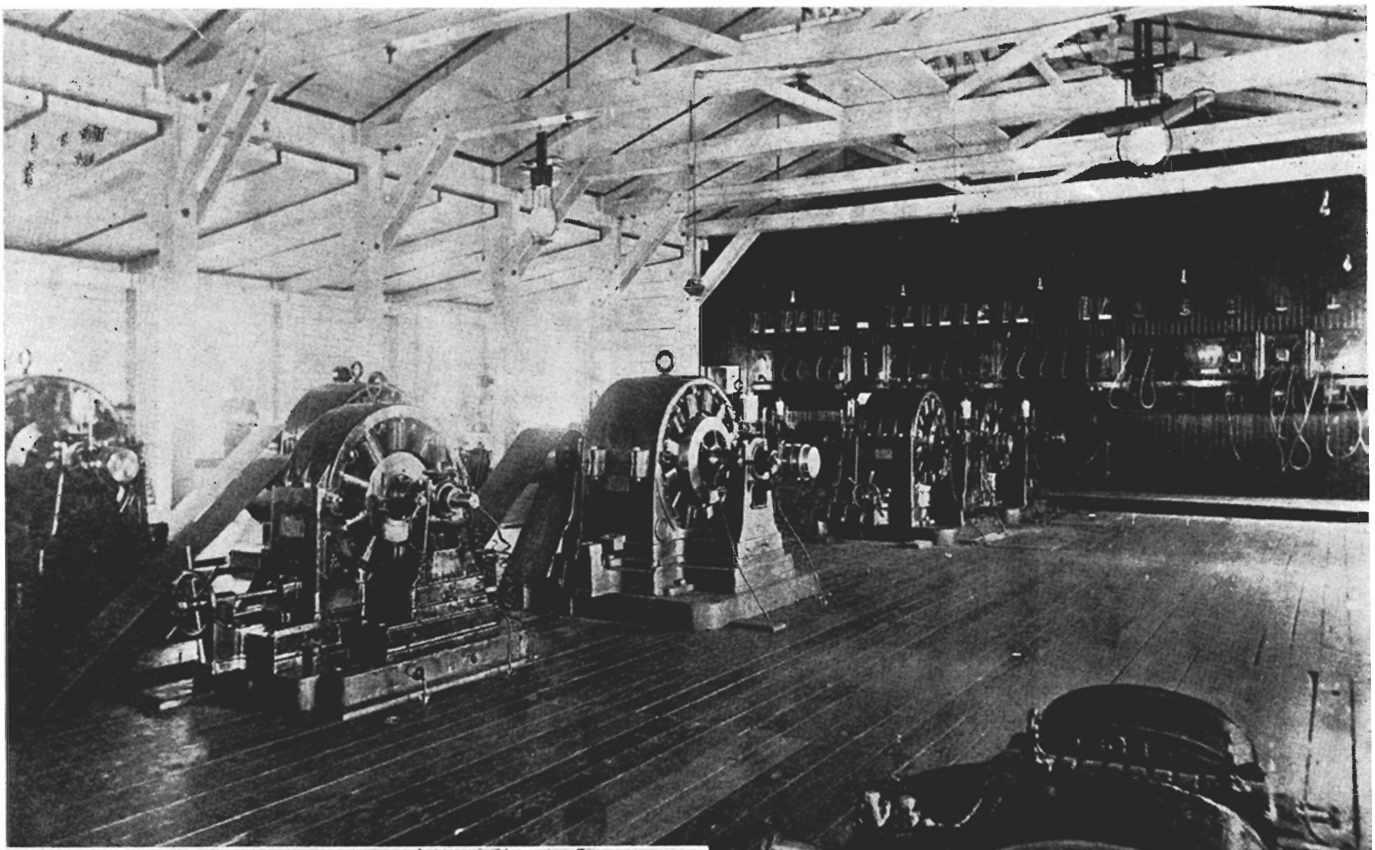


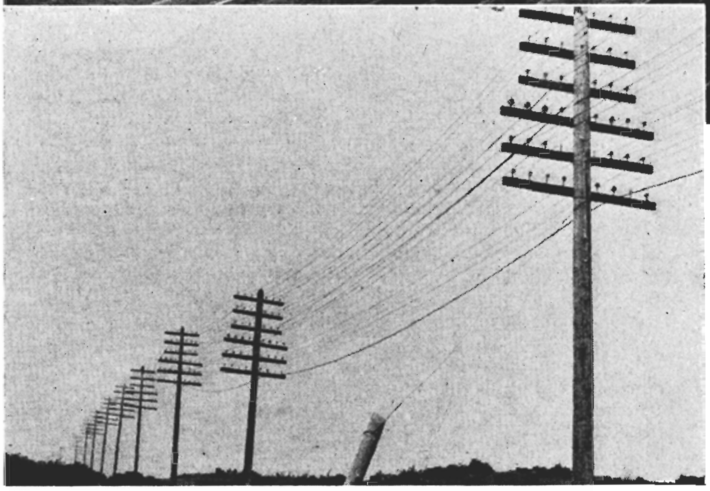
TWIN HORIZONTAL TURBINES WITH CENTRAL INTAKE

*Photo courtesy of "Mechanical Engineering"*

**Above is chart showing various arrangements of reaction (Francis) runners in use in early hydro electric stations. Below is the testing flume of the HOLYOKE WATER POWER CO. placed in operation in 1882. It was the first commercial flume in the U.S. for scientific testing of water wheels on a large scale and during its 55 years of life over 3,000 tests were made, a pioneering development by an operating company which undoubtedly has contributed much to the efficiency gains in hydraulic turbine operaton.**







**1889. Historic hydro electric development at Willamette Falls on the PORTLAND GENERAL ELECTRIC system, first to transmit power at 4,000 volts. Eight single phase, water wheel driven alternators with a total capacity of 720 kw, and eleven 100-arc lamp generators made up the initial installation. Power was transmitted 14 miles to Portland over the transmission line shown on the left. The art of synchronizing separate units to operate as one was not practiced at that time, so a separate circuit had to be run for each machine. The extravagant use of copper imposed by this limitation of the time is apparent.**

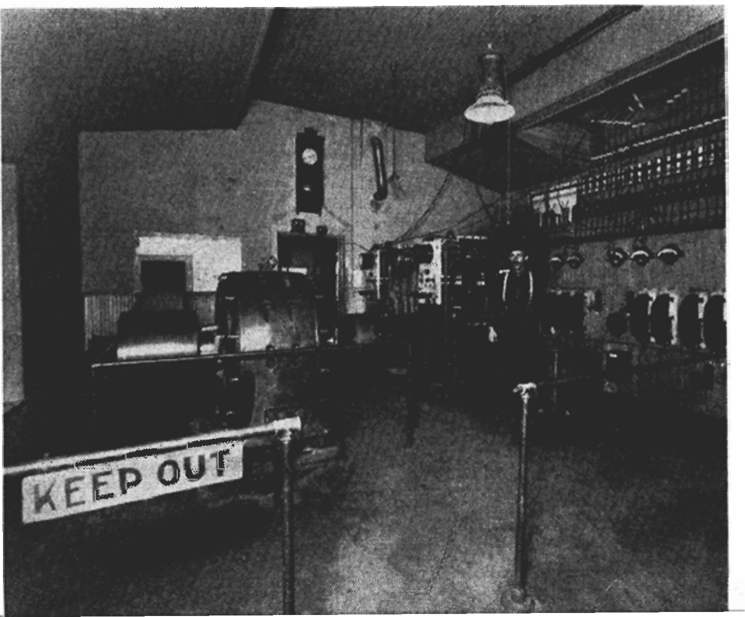
ers were characterized by a relatively small flow and a rapid decrease in elevation which suggested high head stream flow developments. As most of these sites were located at considerable distance from the load centers, the economic transmission of power thus developed became of major importance. The western companies, which pioneered the high head developments, necessarily also pioneered in transmission design at the higher voltages necessary to bring power to the areas of use with minimum loss.

Elsewhere in the country hydro electric developments were characterized by the utilization of streams with greater volumes of water but much more gentle profiles. Generally speaking, transmission distances were shorter but, as the amounts of power transmitted were large, a rapid development of the medium transmission voltages resulted.

River development by the power companies generally was undertaken with the definite plan for complete utilization of the river in view. Contrary to many people's thinking, hydro electric power is not necessarily cheap power if the initial investment

*(Continued on page 232)*

**1889. Sparta, Wis., was served by this plant in the early days, although the generator shown here was purchased about 1904 and is still operating on the NORTHERN STATES POWER COMPANY system. Louis Berg, operator shown in the picture, is still employed by the company.**



Drawing of early Pelton (impulse) Wheel and electric generator installed in pioneer western hydro electric installation. High pressure water jet impinging on the buckets turns the wheel. From this crude beginning high efficiency Pelton units were developed for modern high head plants located in western mountain areas.

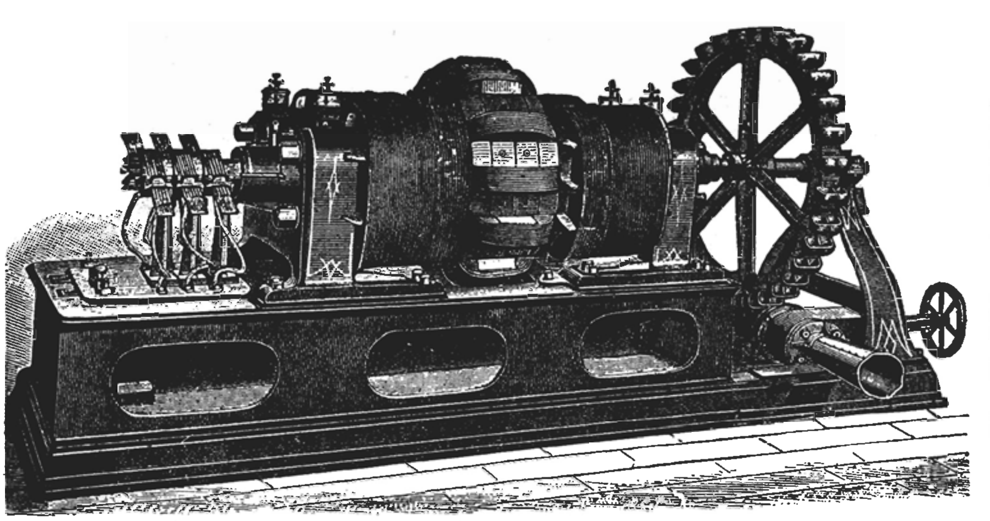
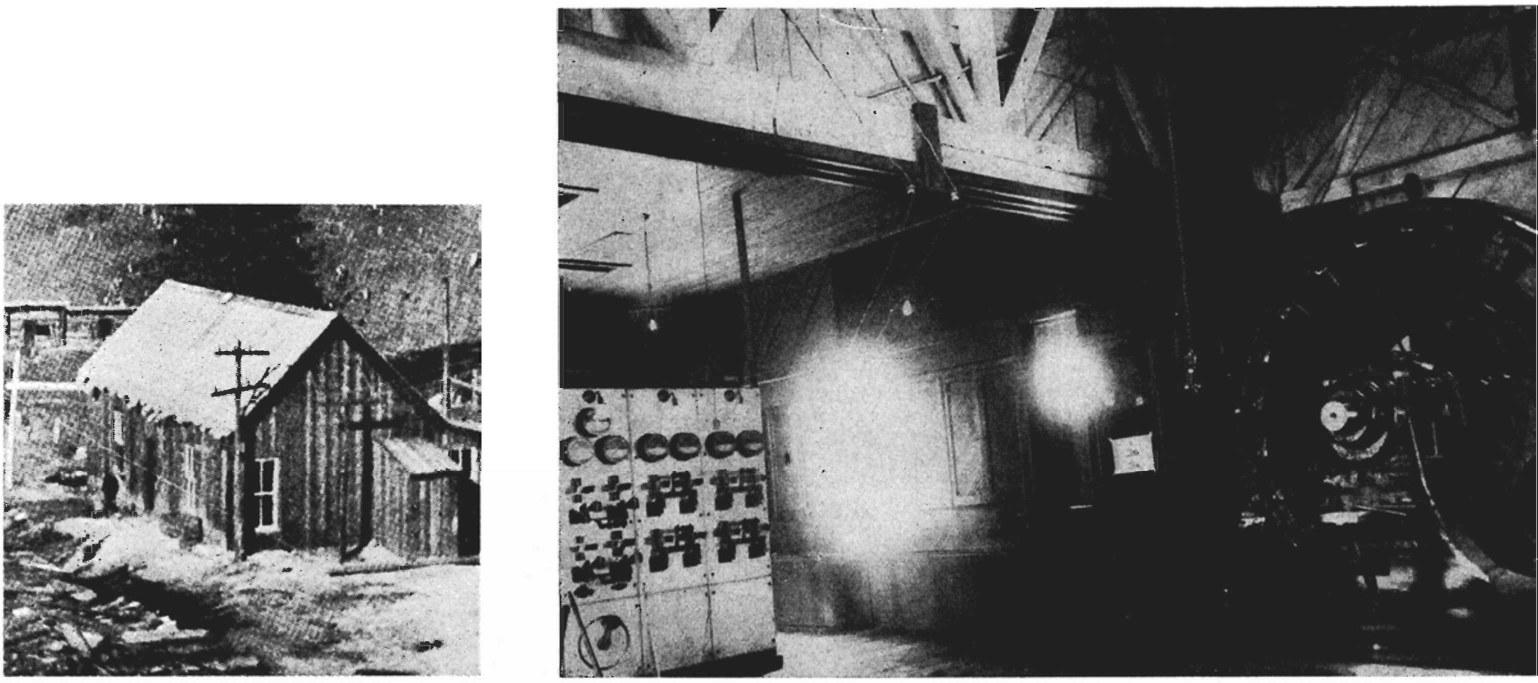
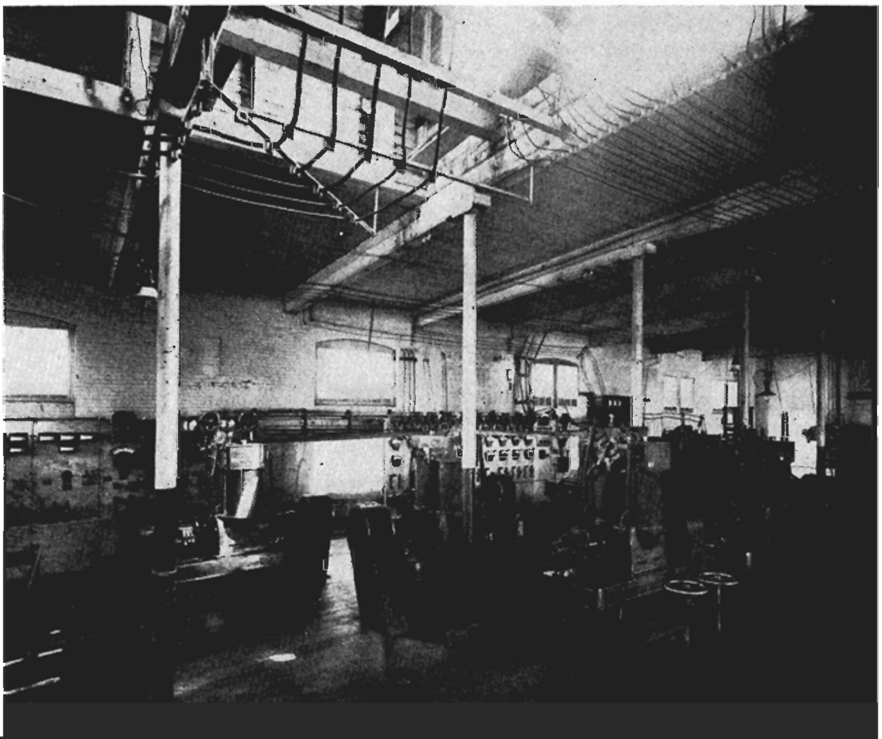


*Photo courtesy of "Mechanical Engineering"*

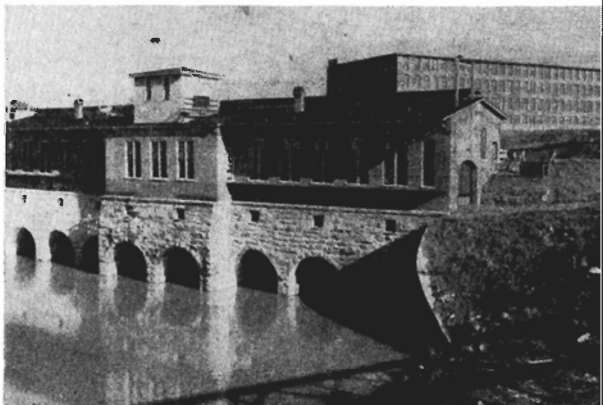


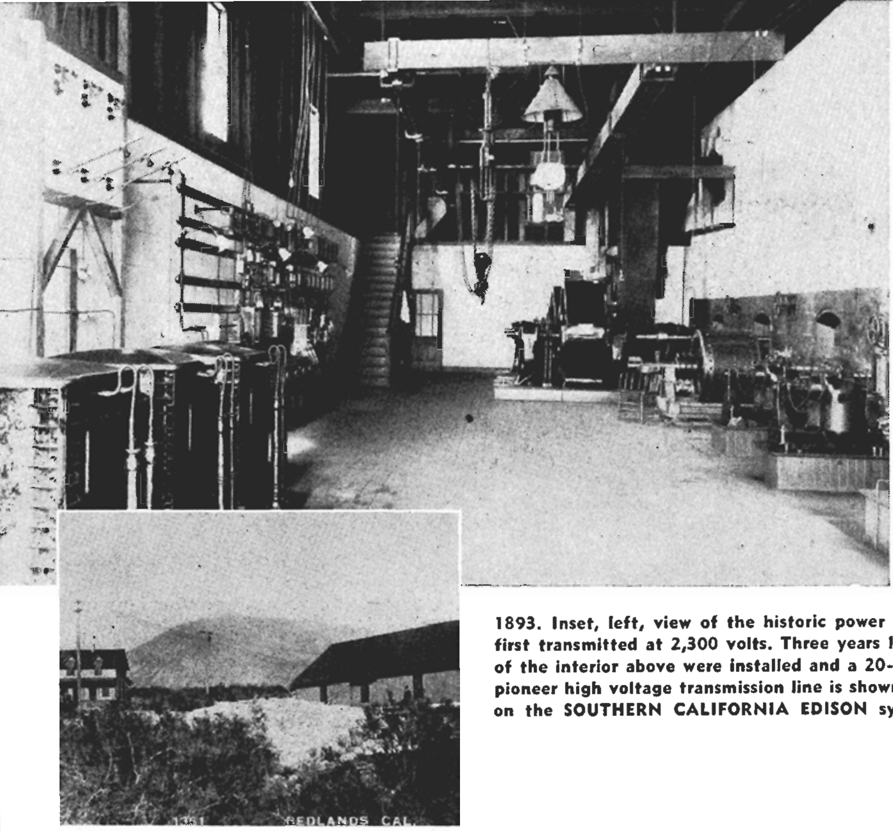
1891. Interior and exterior views of the Ames Plant of the WESTERN COLORADO POWER CO. as it looked in 1891. This installation was a pioneer attempt to transmit hydro electric power for industrial use, a 3,000 volt single phase power line carrying its output to the Gold King Mine nearly three miles away. The economy of alternating current transmission was apparent in this installation, the cost of copper being about $700, or 1% of the estimated cost had d-c transmission been attempted.

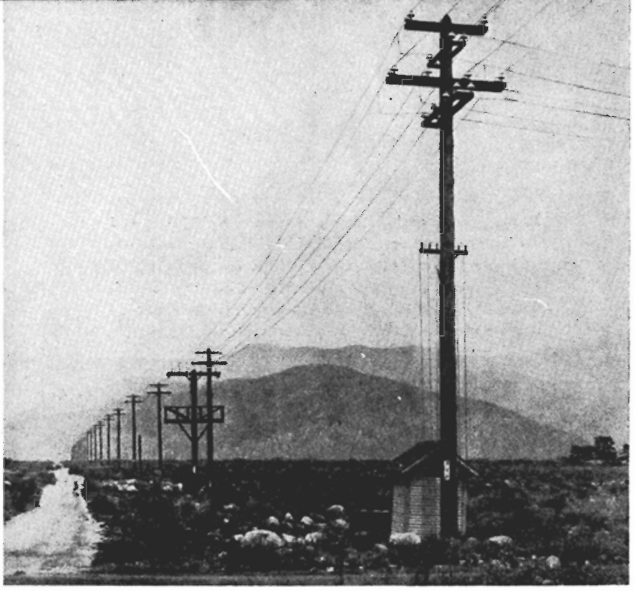


Excellent interior view of the Spokane Station, WASHINGTON WATER POWER CO., taken in about 1903 showing five bipolar dynamos belt driven from water wheels on the lower floor. Note switchboard development, exposed wiring runs, and arc lamp illumination of the station.

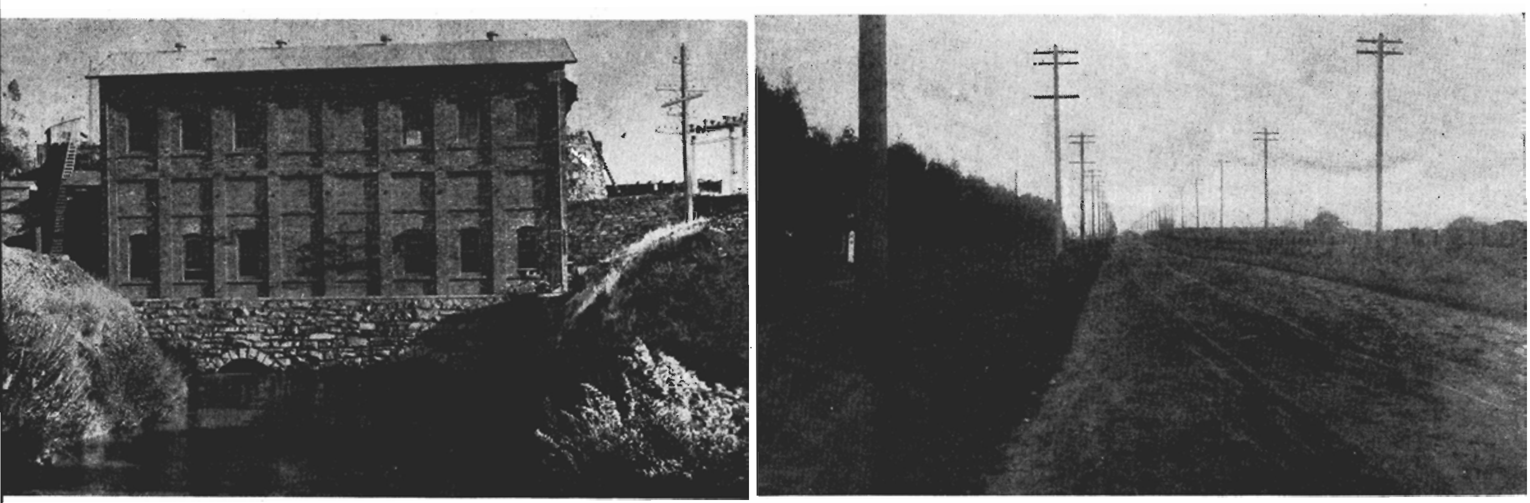
1896. This hydro electric plant in central South Carolina was the first source of hydro electric power in the area now served by the SOUTH CAROLINA ELECTRIC AND GAS CO. Starting with three units, it now has seven generators and is still in operation.





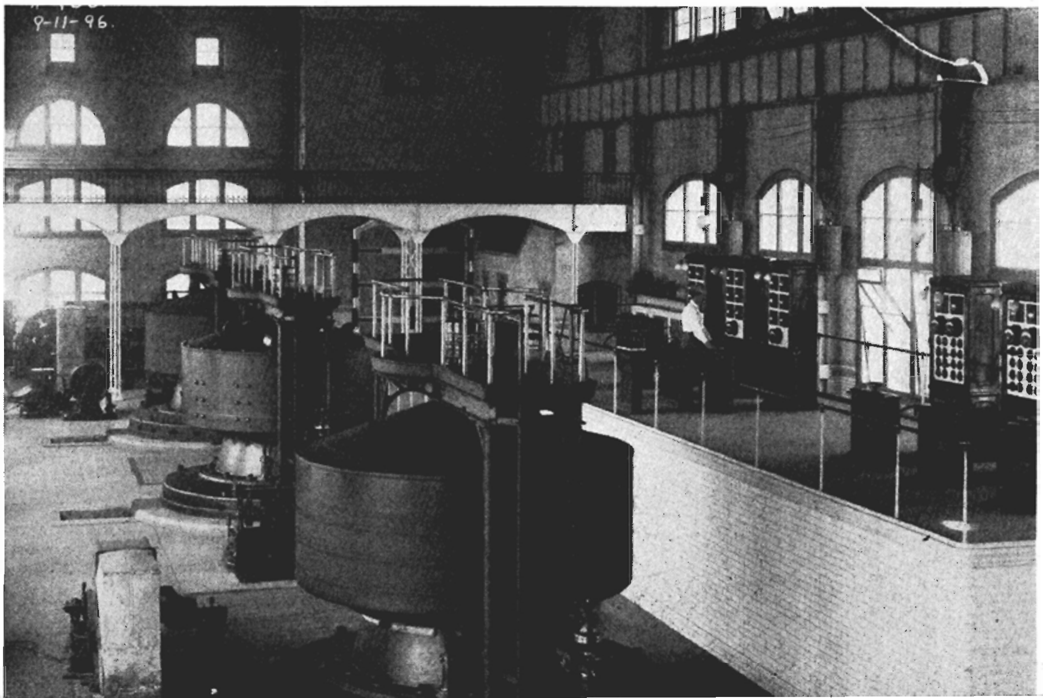


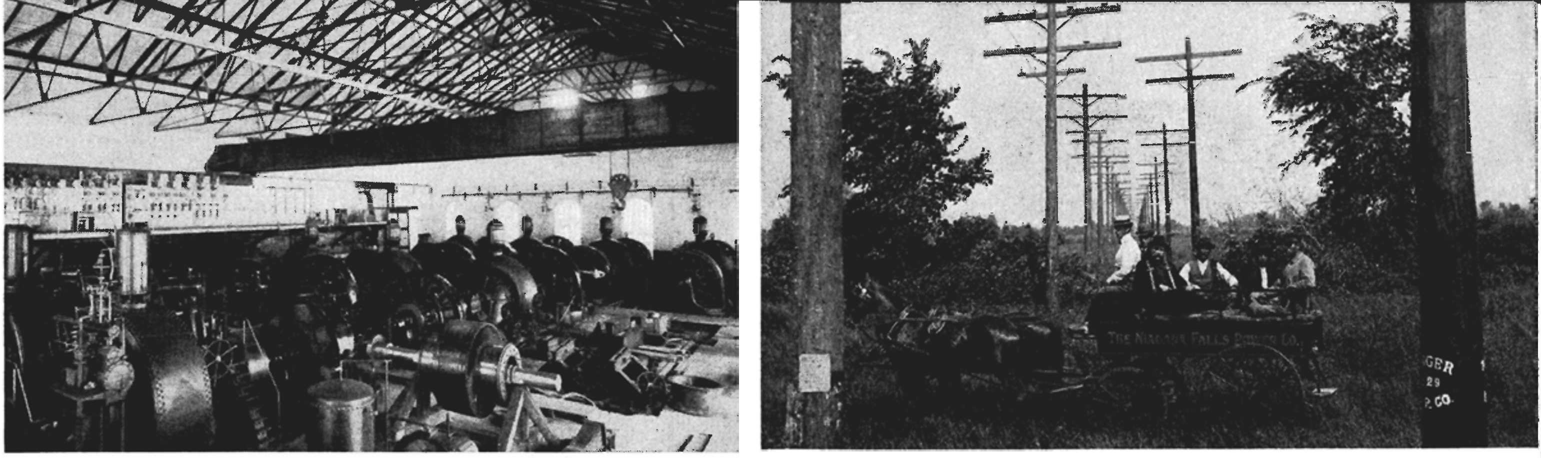
**1893.** Inset, left, view of the historic power house near Redlands, Calif., from which three-phase power was first transmitted at 2,300 volts. Three years later the plant was enlarged and transformers shown on the left of the interior above were installed and a 20-mile, 11-kv line to Riverside, Calif., completed. This two circuit pioneer high voltage transmission line is shown at the right above. Mill Creek Plant, which is still in operation on the **SOUTHERN CALIFORNIA EDISON** system, marks an important milestone in transmission progress.



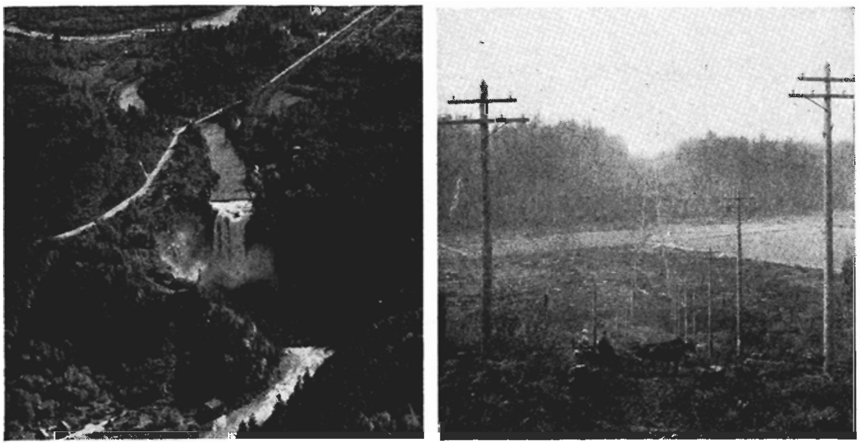
**1895.** Folsom Power House is the pioneer hydro electric station on the **PACIFIC GAS & ELECTRIC CO.**'s system, being placed in operation July 13, 1895. Its 4,000 hp output was transmitted 22 miles to Sacramento over the 11 kv line shown at the right above.

**1896.** Adams Station of the **NIAGARA FALLS POWER CO.**, the first large central station, utilizing water power available at Niagara Falls, consisted of these three 5,000 hp units operating under 140 ft head. Interior view of the generating room and the three units is shown.



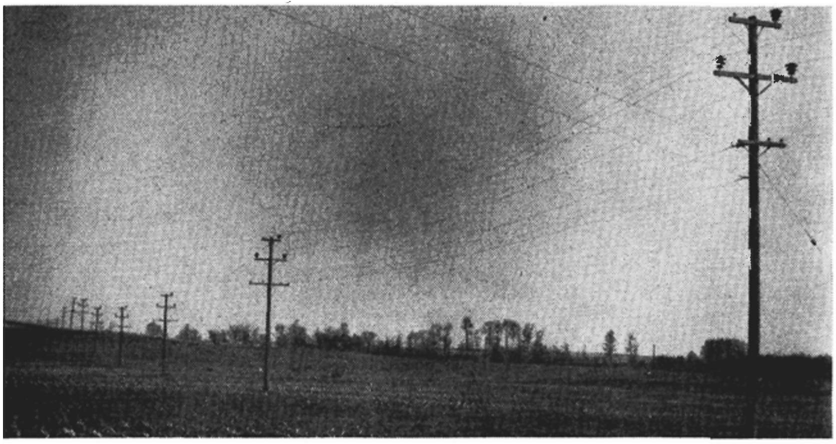


**1896.** Left, above, Schoellkopf Station of the **NIAGARA FALLS POWER CO.** looked like this in 1896. Units were rated between 1,650 and 2,900 hp and operated under 210 ft hydraulic head. Right above, power from Niagara Falls Adams Station was transmitted 22 miles to Buffalo over these two 11 kv circuits. Later two more circuits were added and the voltage raised to 22,000 volts. Some of the original conductors are still in use after 50 years of service.

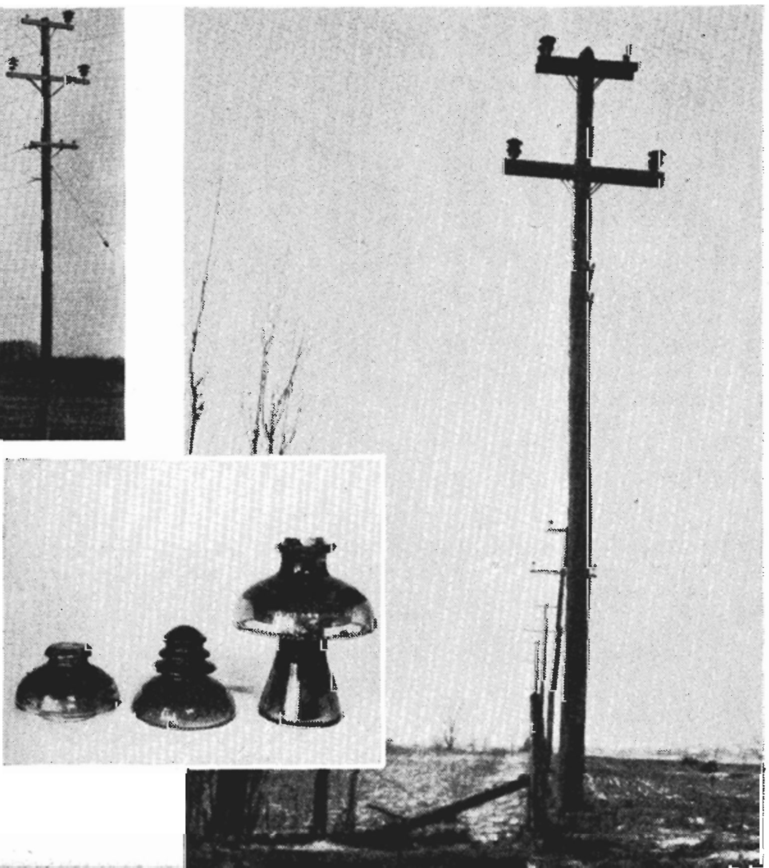


**1899.** In the northwest the **PUGET SOUND POWER AND LIGHT CO.** used hydro electric energy developed initially at the Snoqualmie site shown left above. Power from this station was carried 35 miles at 30 kv over transmission lines shown above. The rapid increase in transmission voltage during the 1890's indicated the ability of early designers to provide adequate electrical equipment, but the 60 kv level for transmission appeared to be the limit unless improved insulators could be developed.

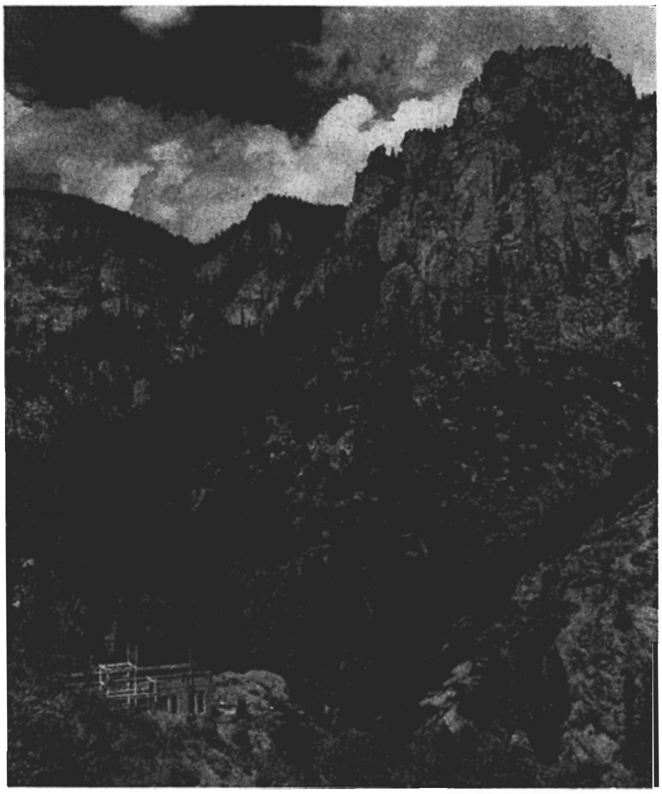
**1899.** Above, Colgate Power House on the **PACIFIC GAS AND ELECTRIC** system was completed in 1899 and transmitted its power at the 40 kv level, 61 miles to Sacramento, Calif.



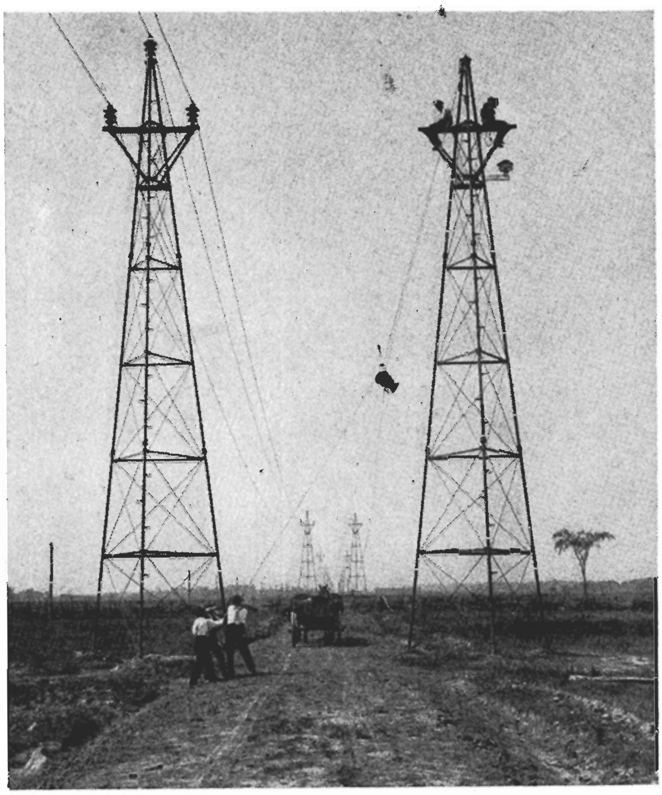
**1906.** 70 kv wood-pole line constructed by **CONSUMERS POWER CO.** between Rogers Dam and Grand Rapids, Mich.



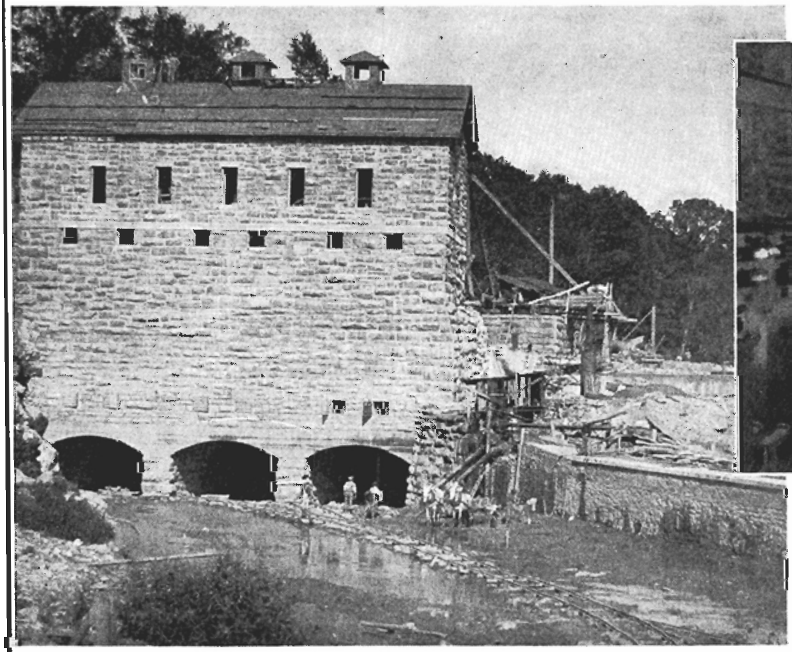
Right, original 40 kv transmission line between Battle Creek and Jackson, Mich. on the **CONSUMERS POWER** system completed in 1903. The short arm at the top carried one phase wire and a ground wire for lightning protection. Inset (left) glass insulator for 25 kv line. (Center) Insulator originally tried on 40 kv line in 1903. (Right) Larger size finally adopted for satisfactory operation. Early 25 kv lines of this company used No. 4 iron wire conductors.

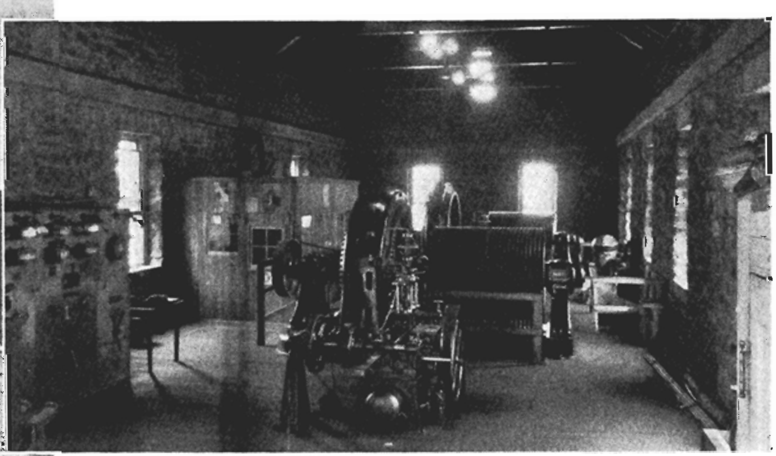


**1900.** Above, Skaguay hydro plant built by a predecessor company of the **SOUTHERN COLORADO POWER CO.** in 1900. Mining activities in the Colorado mountain area gave impetus to the need for electric power, resulting in this plant, operating on a 1,100 ft hydraulic head. Water supply for the station was not dependable and it was connected with the steam plant at Pueblo to provide reserve power for the dry season—one of the first instances of steam and hydro interconnection for maximum reliability of service.



**1906.** Early steel tower design for 60 kv circuits from Niagara Falls to Syracuse, a distance of 150 miles. Towers were made with pipe and later filled with concrete to keep out water. Insulators were four-part porcelain with parts cemented together in the field. All-aluminum conductors spliced with twisted sleeves were used and much of the original line is still in service. This installation is significant as indicating how transmission developments were extending the area over which power could be used from a single generating source.



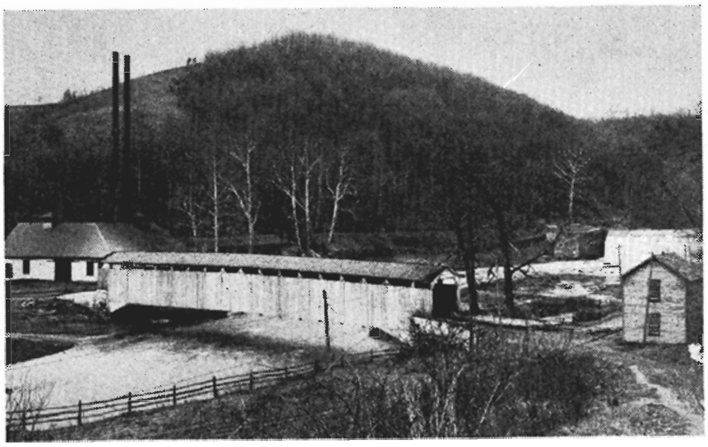


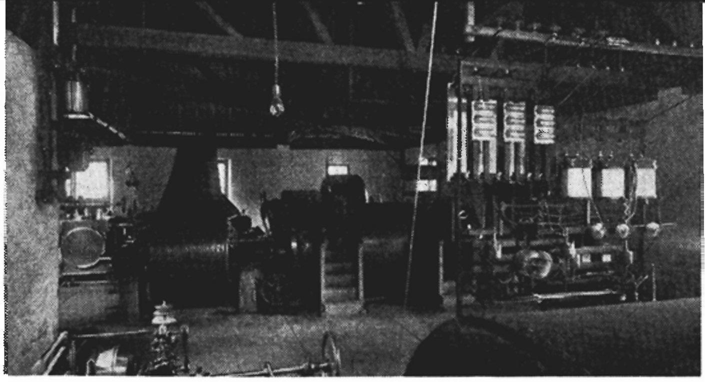
**1904.** These interior and exterior views of an early plant on the **POTOMAC EDISON** system near Williamsport, Md., are typical of the era. Note that the alternators are driven through rope sheaves from water wheels on a lower level.

costs and transmission costs are capitalized in calculating the value of the kilowatt hour delivered to the load center. However, when hydro electric power can be integrated into a system having base load steam plants the result frequently is an over-all improvement in system production efficiency. Under such conditions, hydro electric plants can operate at full capacity during the flood season and conserve their potential energy to handle system peaks during the dry months.

Only in isolated cases will the stream flow be of sufficient regularity to provide adequate power reserves without steam or internal combustion plants to supplement the flow in dry seasons or dry years.

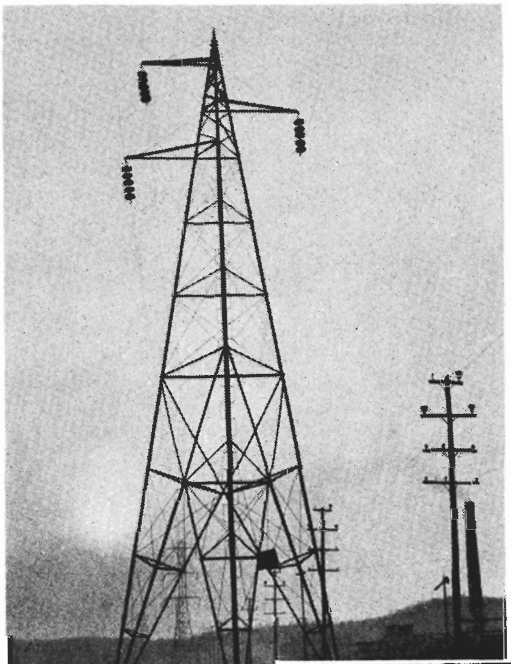
*(Continued on page 235)*

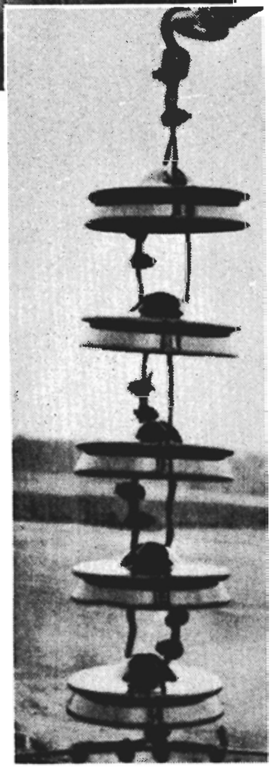




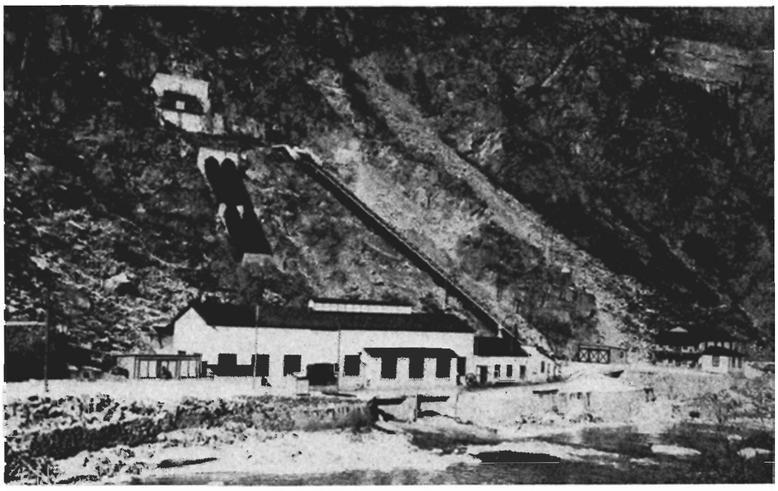
*Photos courtesy of Rumsey Electric Co.*

**1904. Interior and exterior views of an early hydro electric plant at Colemanville, Pa., which provided a steam engine reserve unit at the site of the hydraulic unit. Switchboard arrangement at the right of the interior view is of interest.**

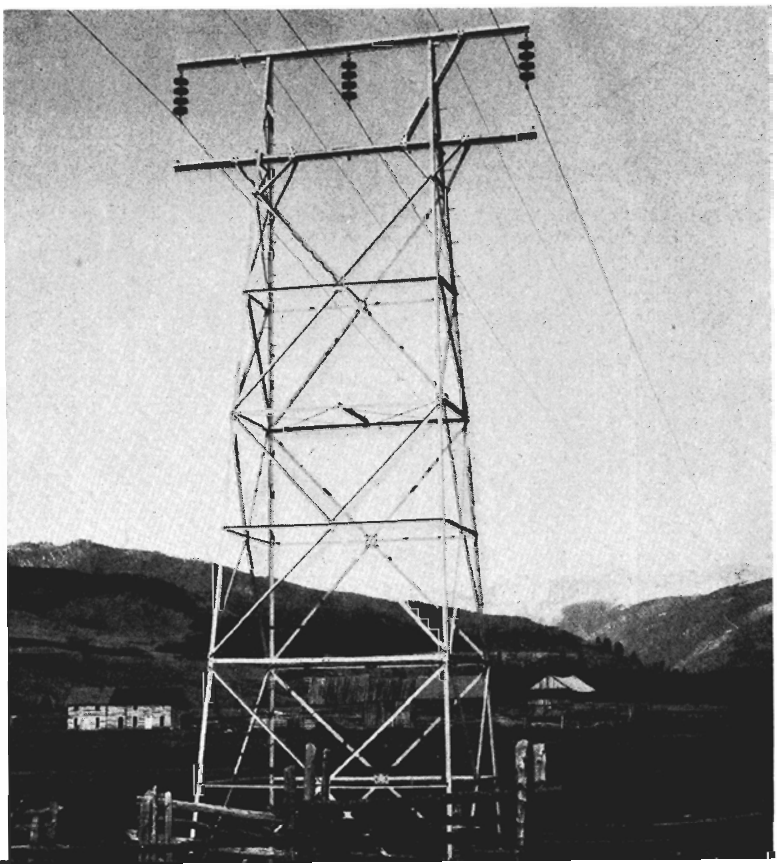


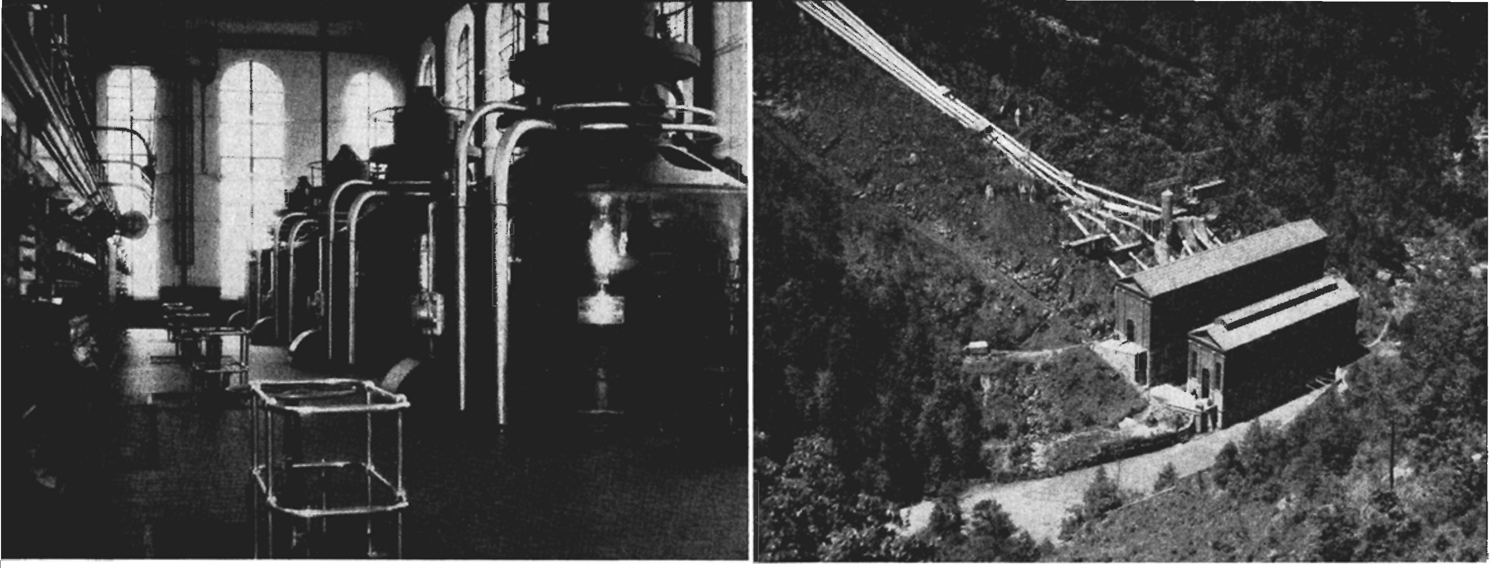


**1908. Original 110 kv transmission line construction on the system of the CONSUMERS POWER CO. showing the windmill type tower and initial use of suspension insulators. The disc type suspension insulators, detail of which is shown in the inset to the right, made possible transmission lines operating at voltages above 60 kv and greatly expanded the economical transmission limits for electrical power.**

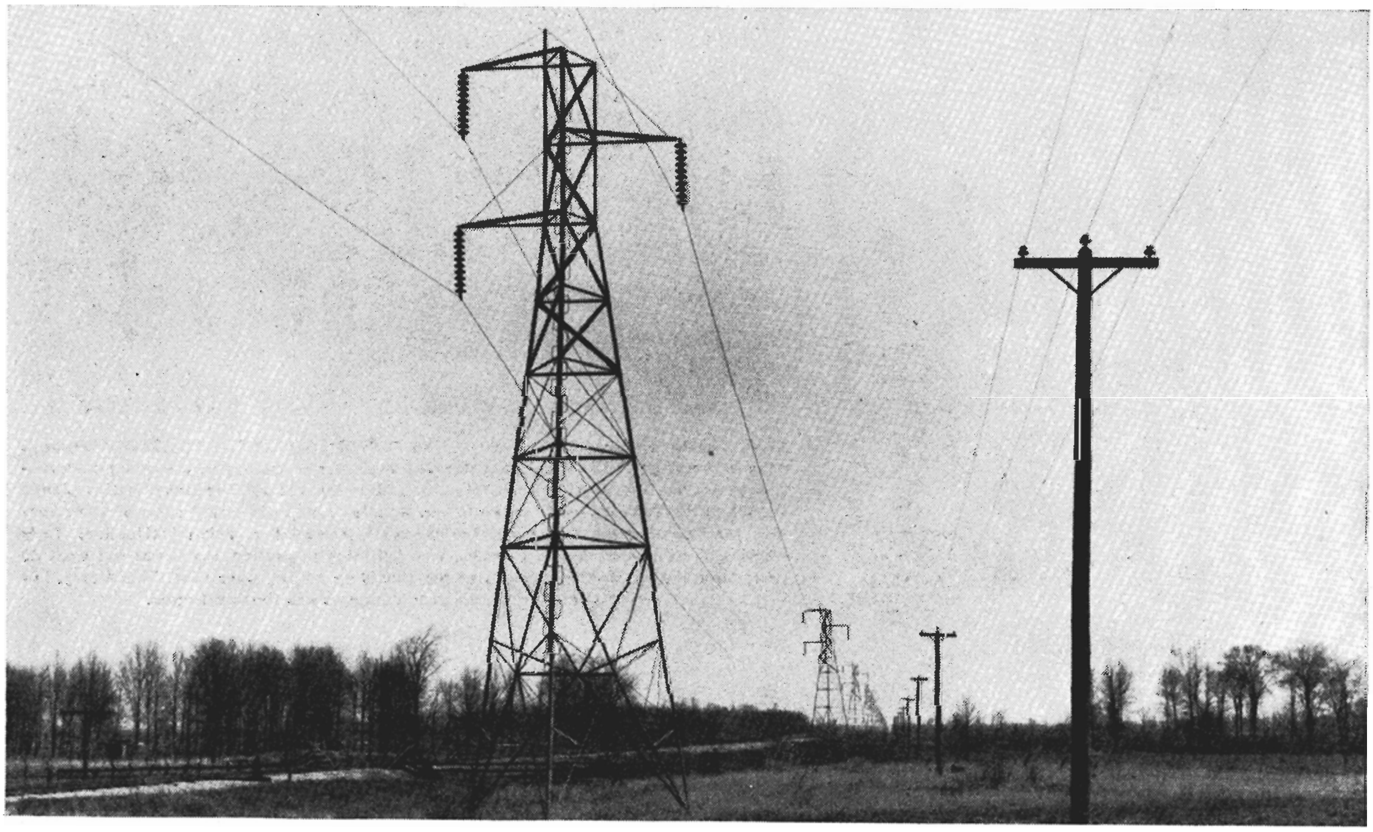


**1909. Shoshone Plant (10,000 kw) of the PUBLIC SERVICE CO. OF COLORADO, built deep in the heart of the Rockies, confronted engineers of the day with weighty construction problems. The pioneer long distance (182 mile) 110 kv line carrying this plant's output to the Denver area is shown below. Double ground wires at the top of the structure for lightning protection were subsequently removed as being ineffective. Early transmission designers lacked experience in lightning protection and it was not until 20 years later that ground wires, with correct shielding angles, were used. The theory, but not the practice, of the early designers was thus confirmed.**





**1913.** Tallulah Falls plant of the **GEORGIA POWER CO.** provided a major generating source for the **GEORGIA POWER** system in 1913 and was one of the first installations designed for inter-system power supply, as the initial capacity of 72,000 kw exceeded the system's immediate generating needs. From a design standpoint, the exposed penstock construction is of interest. The interior view shows four of the six 12,000 kw generating units with direct connected exciters and indicates the trend toward larger and larger machines.



**1912.** First 140 kv transmission line, between Au Sable River and Battle Creek, Mich., on the **CONSUMERS POWER** system. Note that the tower design includes vertical extension for ground wire support and the use of cap and pin suspension insulators in place of the interlink type.

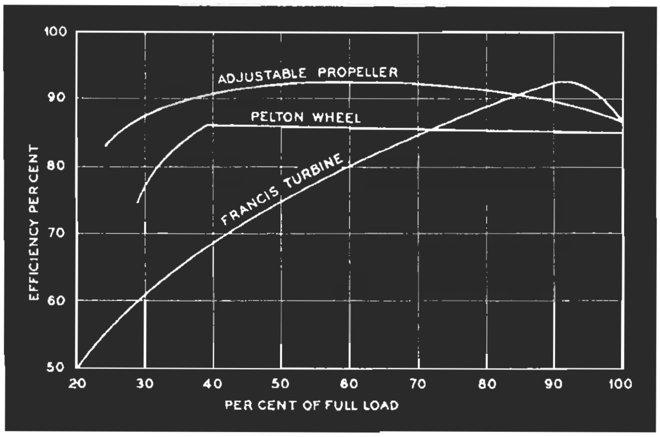
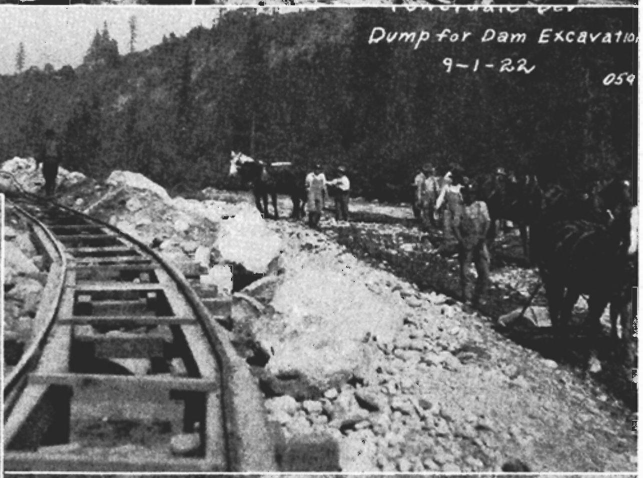
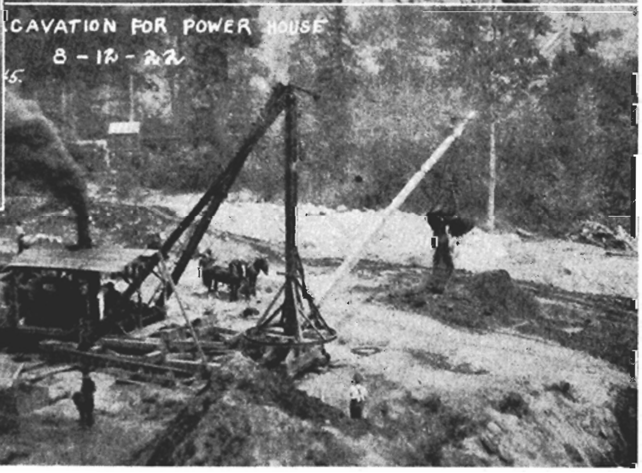


Chart showing relative efficiencies of various types of hydraulic turbine runners. The Pelton or impulse wheel is generally used on hydraulic heads above 500 ft. The adjustable propeller runner is a much more recent development than either the Pelton or Francis types. With the adjustable propeller runner, which is adapted to low head installations, the sustained high efficiency over a wide range in load permits maximum economy in water use. See illustration on opposite page.

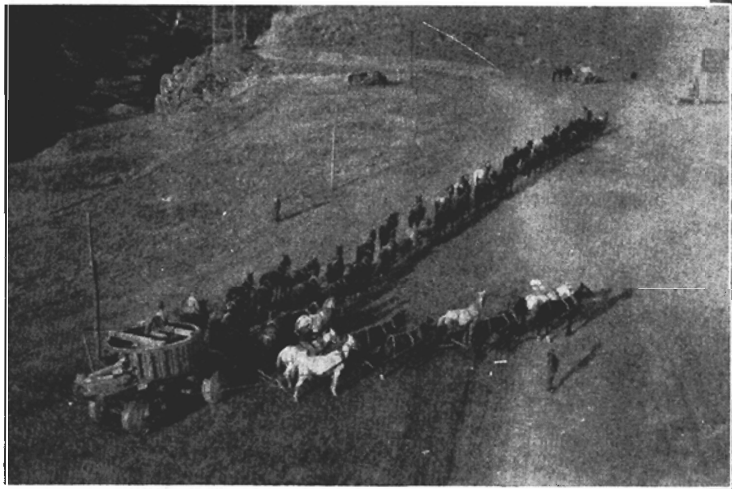
**Right, this 1913 view of construction on UTAH POWER AND LIGHT'S Grace Plant shows the pick and shovel brigade necessary in those days. The two other views below it, taken in 1922 on PACIFIC POWER AND LIGHT'S Powerdale development, show that even at that late date construction equipment was still slow and crude and that the horse was a major element in operations.**





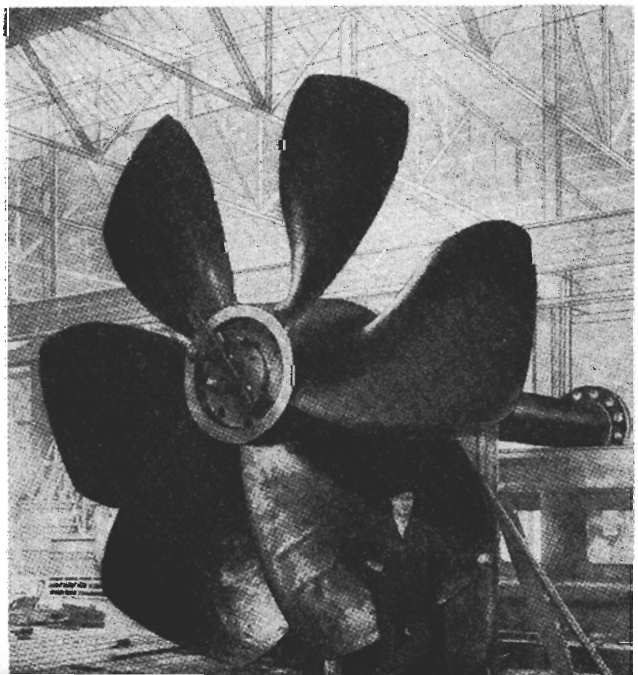
Likewise, the popular idea that reliable electric power can be obtained through flood control projects is a fallacy. Reservoirs which are designed to catch surplus flow during the flood seasons are not a source of power. Once filled, these reservoirs can produce power, up to the limit of their storage capacity. Flood control, therefore, provides only intermittent periods of power production, the kilowatt hours from which can be used advantageously only if utilized to displace fuel on an existing system.

Hydro electric engineers did not have the opportunities available to steam designers for economy improvements, although considerable improvement in the efficiency of water utilization resulted from the studies of wheel, nozzle, intake and draft tube design. Hydro electric history is highlighted by the engineers' ability to overcome natural obstacles in utilizing the head and flow of America's power streams. This contribution to the development of the electrical industry has resulted in over-all system



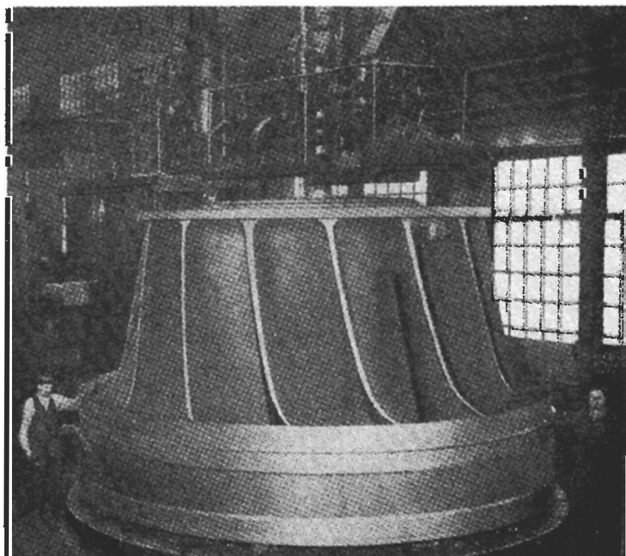
**Early in the twentieth century transportation problems for heavy equipment were solved by horse power and man power. Above is the method of hauling the equipment for the first Kern River plant of the SOUTHERN CALIFORNIA EDISON CO. in 1906. The wagon had wheels of solid oak 36 inches in diameter and 18 inches wide at the axle, with 12-in. rims bound on the edges by 4-in. steel tires. It was pulled by a 48-horse team, 17 spans of which provided main haulage with two "snatch" teams to turn and maneuver**

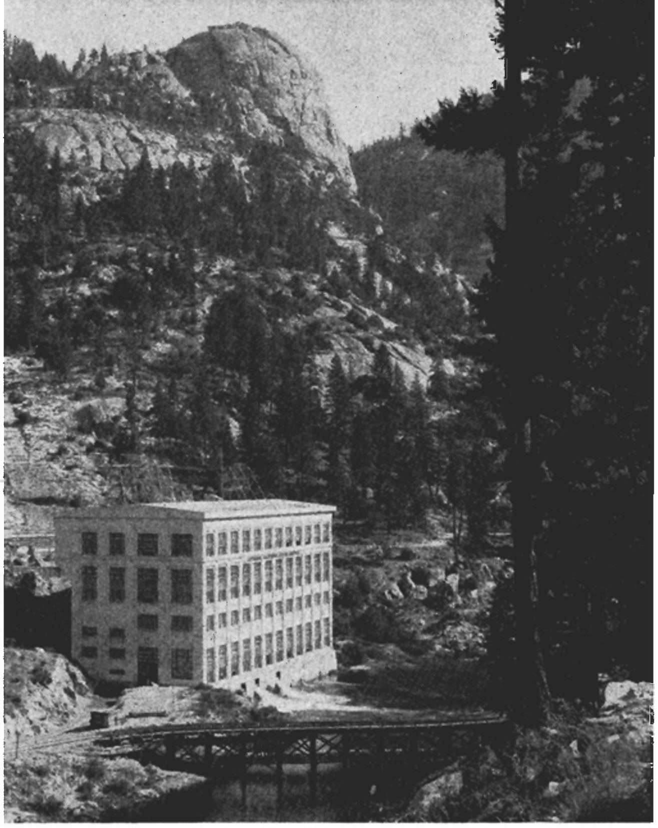
*Photo courtesy of "Mechanical Engineering"*



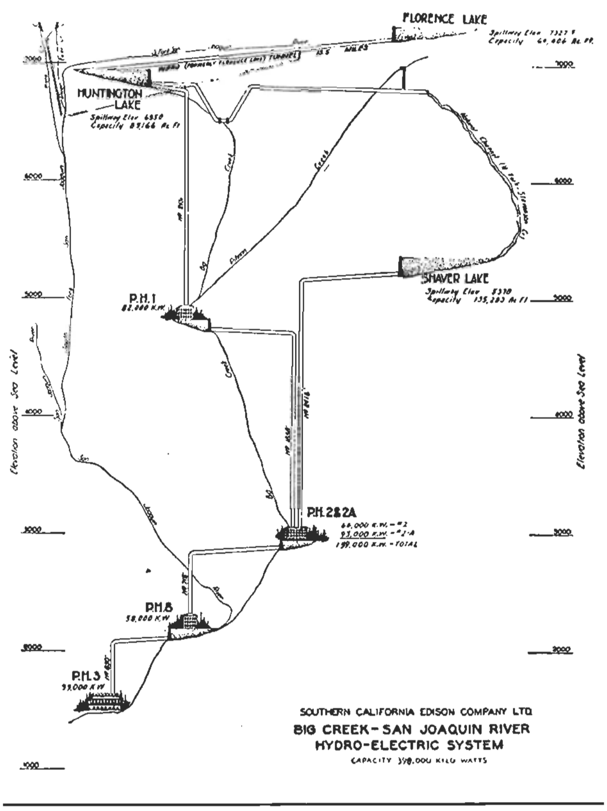
**Views of two types of water wheels used in modern low and medium head plants. Left the adjustable blade (Kaplan) runner which provides high sustained efficiency over various loading conditions in medium low head installations. Right — the reaction (Francis) runner.**

*Photo courtesy of "Mechanical Engineering"*





**Hydraulic development by the electric companies early envisaged complete utilization of streams and rivers. In the west, SOUTHERN CALIFORNIA EDISON'S Big Creek project, Power House No. 1 of which was completed in 1913, is an excellent example. The diagram on the right shows that the waters of Big Creek and San Joaquin River are utilized over their entire flow from 7,300 ft elevation to about 1,600 ft elevation. Construction difficulties involved in utilizing this vast, mountainous water shed were many, as indicated on the top of the adjacent page. Capacity from this development totalled nearly 400,000 kw.**

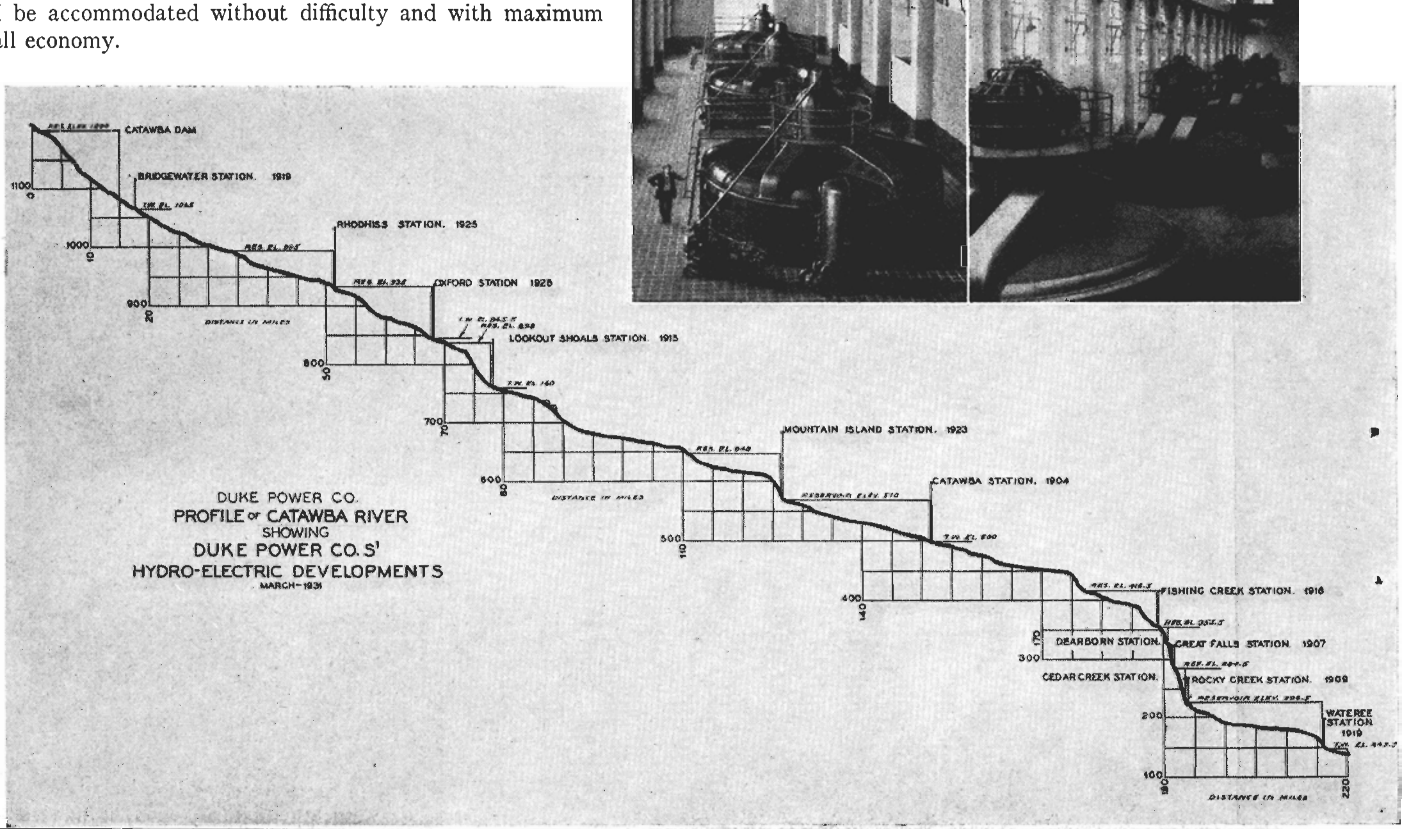


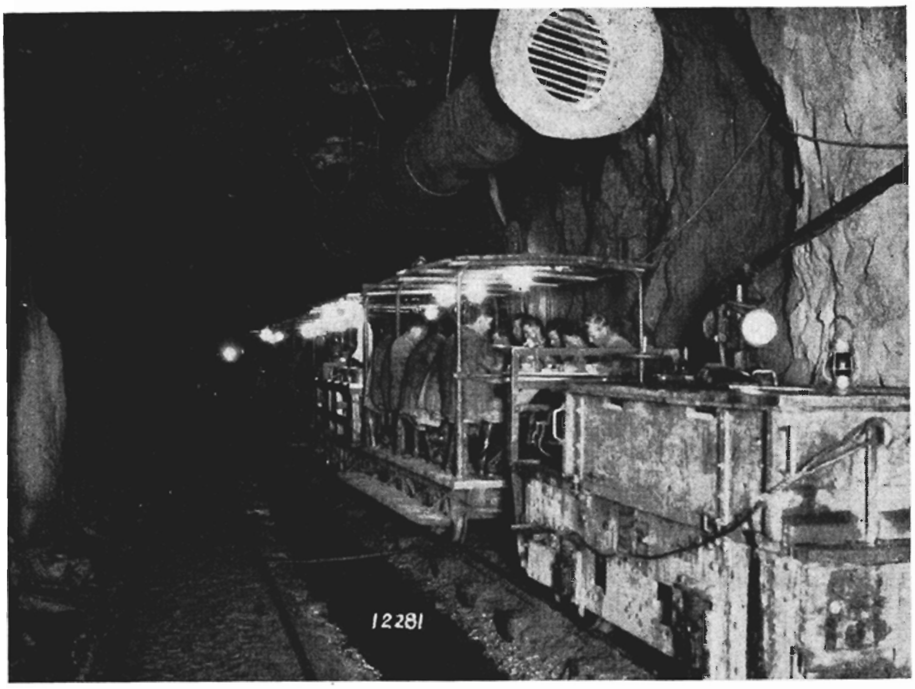
Diagrammatic profile of the Big Creek-San Joaquin River hydro-electric development

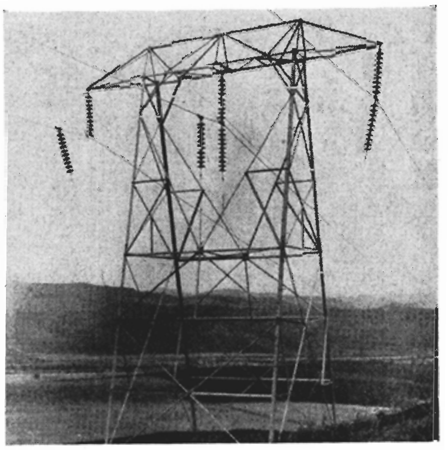
economy and a resultant decrease in cost of power to the consumer.

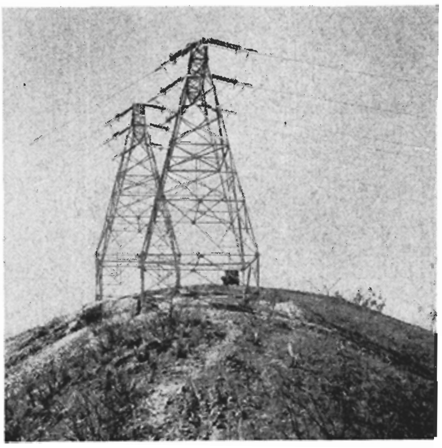
The future of hydro development by the business-managed companies is clouded by the uncertainties of governmental attitude on flood control. It would appear that the solution most advantageous to both the customer and the taxpayer would be the absorption of power developed as a by product of flood control into existing power systems where its seasonal variations could be accommodated without difficulty and with maximum overall economy.

**Along the eastern seaboard, DUKE POWER CO.'s development of the Catawba River is another excellent example of water utilization over an entire water shed. The accompanying profile shows the progressive development of this river from 1904, when the initial plant went into operation. Insets show two of the plants installed in the early years. On the left, the Lookout Shoals Station, completed in 1915; on the right, the Wateree Station of 1919. The plan, conceived in 1904, was completed in 1928 when 10 of the possible 13 sites were fully developed.** *Photos courtesy of Allis-Chalmers Mfg. Co.*





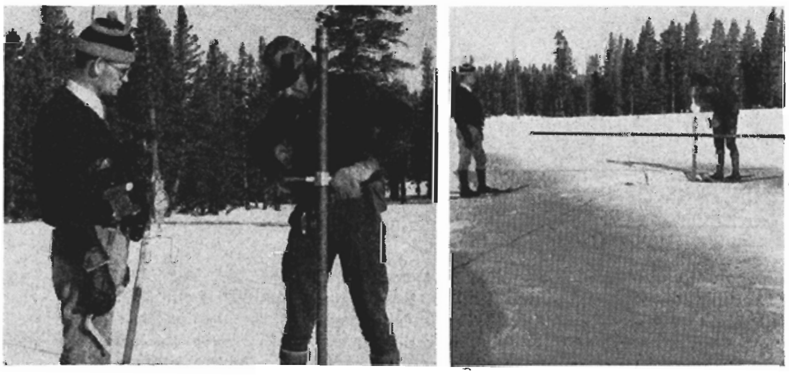




**Above—In driving one of the main tunnels for the Big Creek project in 1920, workers were provided with hot meals by means of this electrically propelled dining train. This tunnel was driven through 13½ miles of solid granite and this scheme provided about the only practical way of feeding crews deep under the divide.**

**Transmitting the large quantities of energy available at Big Creek to the Los Angeles area required still higher transmission voltages. Initially, 150 kv transmission was used for this 240 mile circuit; this voltage subsequently was raised to 220 kv in 1922, adding greatly to the capacity of the original line, a standard tower of which is shown top right. Below this are two of the high strength towers used on this circuit, employing double high strength insulator strings.**

*Photo courtesy of Lapp Insulator Co.*



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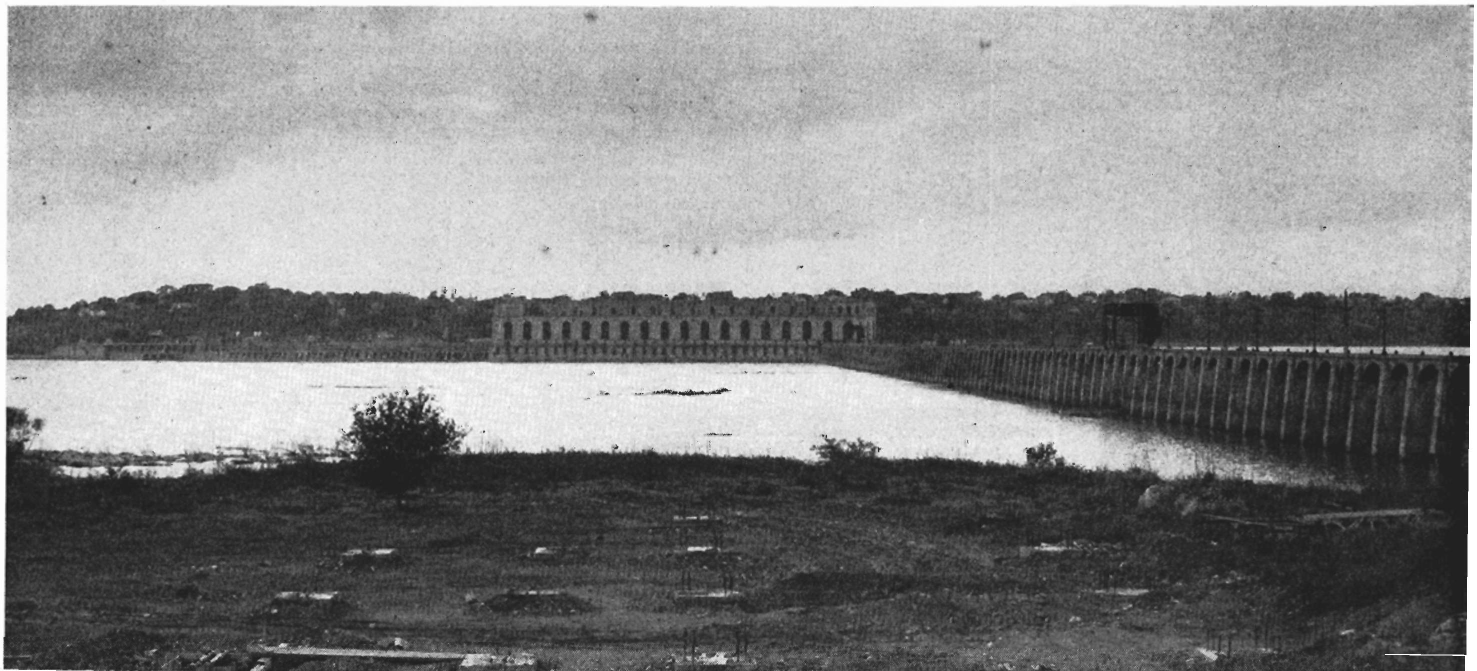
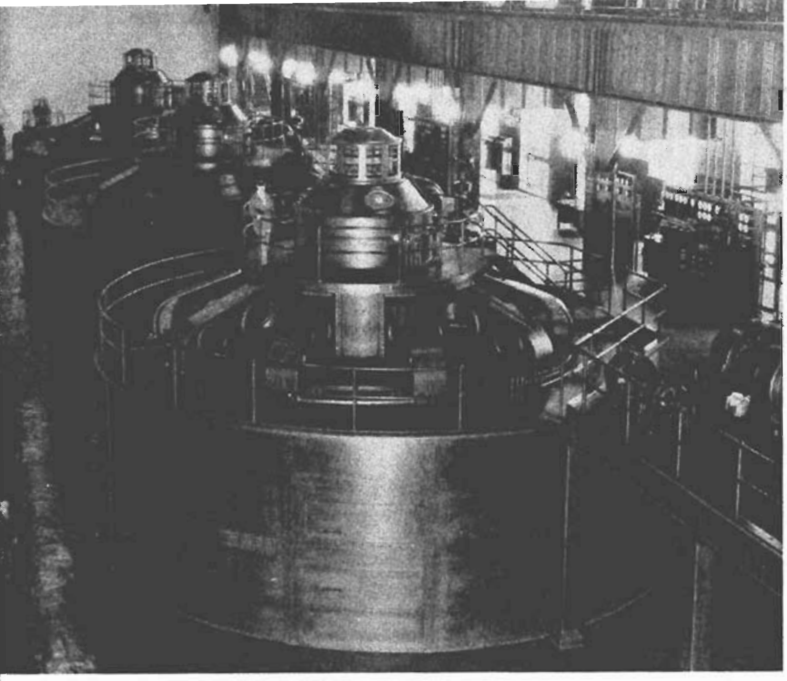
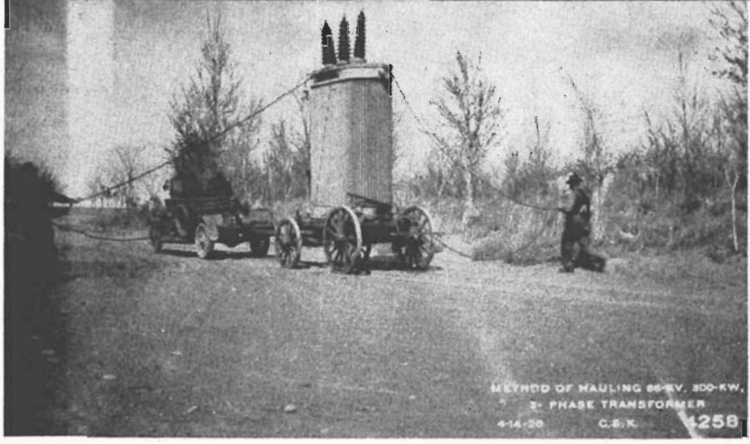
**For the most efficient use of coordinating steam and hydro generating facilities, stream flow must be forecast with reasonable accuracy. By snow surveys in the winter, which measures both the depth and water content of the snow, system operators can predict potential available hydro energy for the ensuing year and schedule plant operations accordingly. Water content is determined by weighing a standard tube of snow as shown.**

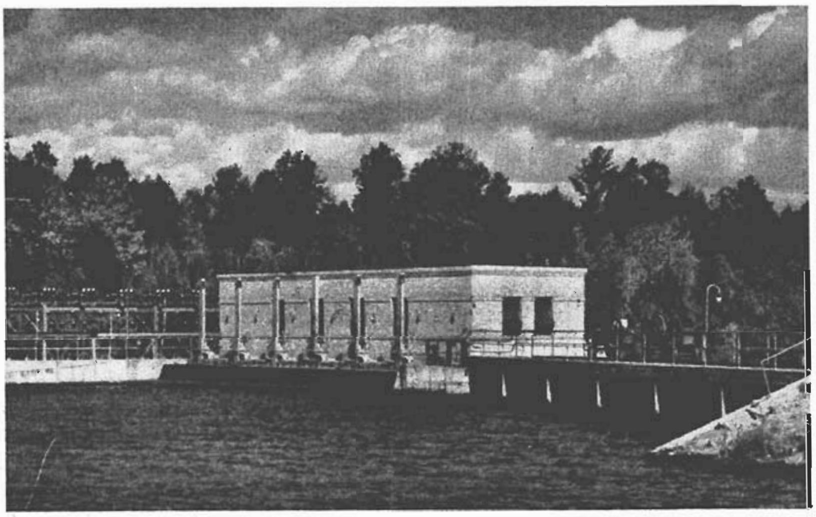
**1913. Harnessing the large flow low head rivers of the Middle West was successfully accomplished at the Keokuk development of the UNION ELECTRIC CO. in 1913. In contrast to the relatively small flow by high head of western plants, this unit utilizes the vast quantities of water available in the Mississippi at a head of 32 feet to develop 113,000 kw.**

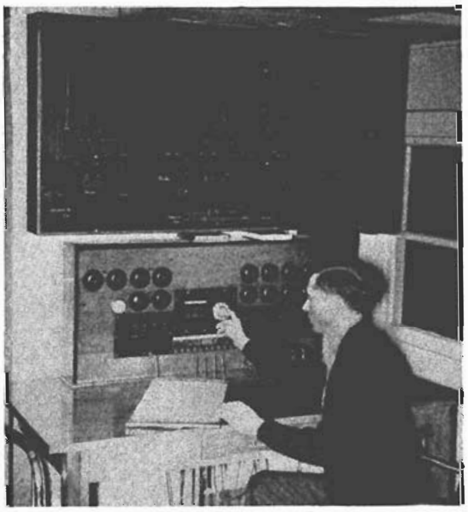






**1923.** Left—These three 65,000 kva hydro electric generators were the largest of their type when installed in Schoellkopf Station of the **NIAGARA FALLS POWER CO.** in 1923 and were the first generators equipped with a.c. auxiliary generators on the shaft of the main unit. Where applicable, larger sized units permitted economies in plant cost. Above—in the early 20's the horse was replaced by the gasoline motor, but transport equipment is still crude. Here, a 66 kv. transformer is being moved into position on the **PACIFIC POWER & LIGHT** system.

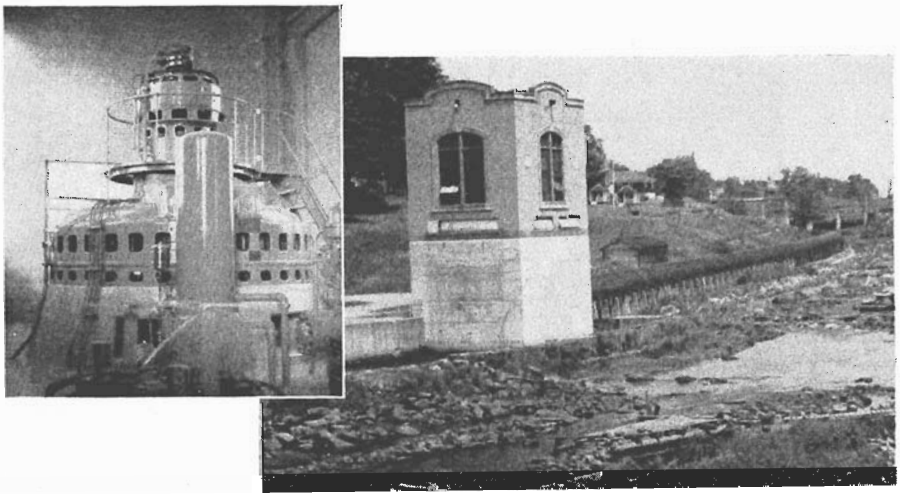


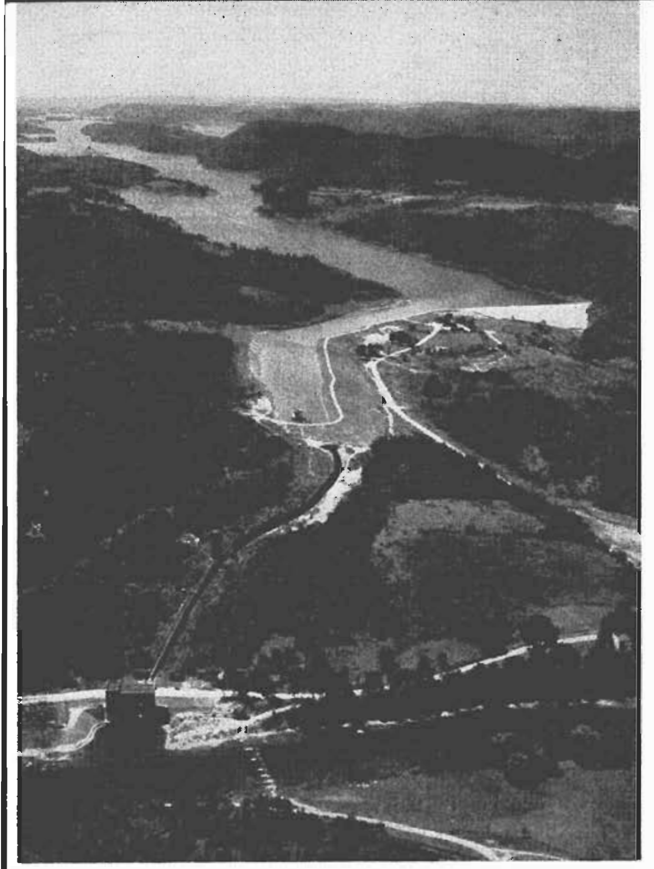


**1923.** Above left—Johnson Falls hydro plant of the **WISCONSIN PUBLIC SERVICE CORP.**, one of the pioneer completely automatic hydro stations. Right—the control panel for automatic hydro plant operation located in the High Falls Station of that system. Automatic operation and remote control resulted in considerable economies that gave new economic life to older hydro electric developments and assured better coordination between plant operation and stream flow. Protective features which shut down equipment before serious damage greatly improve station availability and thus effect a reduction in system reserve capacity requirements. A total of eight plants on this system are now under automatic operation, effecting a 50% saving in their operating costs.

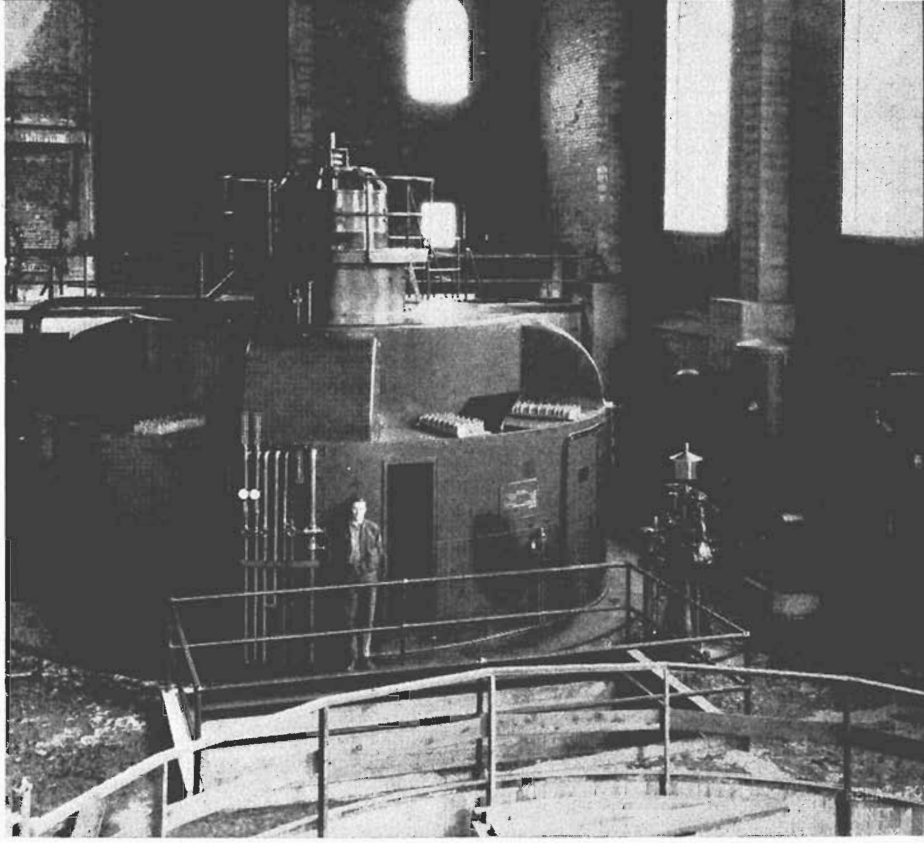
**1924.** Below—The 12,500 kw Poole Plant of the **CALIFORNIA ELECTRIC POWER CO.** had the distinction of being the largest hydro plant operating at an elevation of over 7,800 ft. The static head above this was 1,675 ft with a forebay elevation of 9,500 ft.

**1926.** Automatic operation permits maximum development of stream flow by making economic utilization of small capacities. This automatic hydro plant on the **BANGOR HYDRO ELECTRIC** system was completed in 1926 (below right). (Inset) Automatic operation likewise can be applied to larger units, as the view of the 14,000 kw, fully automatic hydro unit of the **LAKE SUPERIOR DISTRICT POWER CO.** indicates.

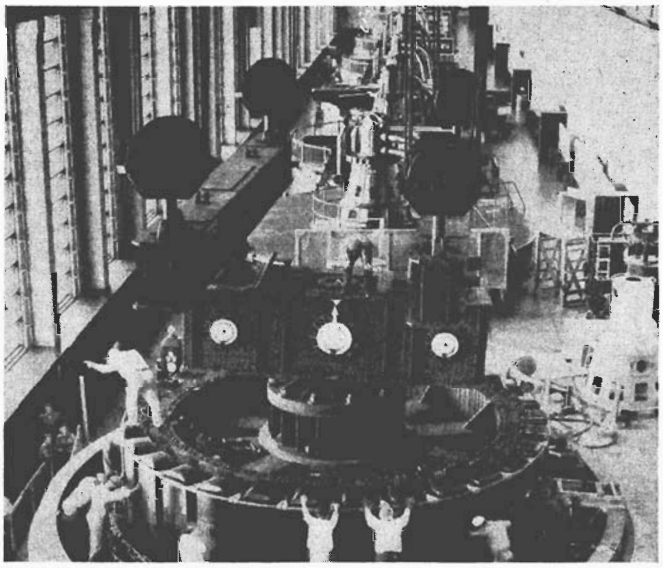




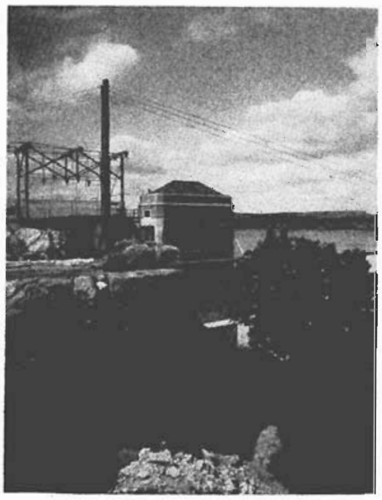
**1928.** Rocky River development of the **CONNECTICUT LIGHT AND POWER CO.** was the first pumped storage hydro electric plant in the U. S. During high water seasons water is pumped up through the penstock to the reservoir in the background, thus regulating flood conditions and providing stored water which returns down through the penstock during the summer and fall, providing 24,000 kw of capacity and raising the river flow to generate additional capacity at a down stream plant. The reservoir, known as Lake Candlewood, has been developed into one of New England's most beautiful recreational areas.



**1926.** By applying air coolers in the generator housing, as was done in this pioneer installation on the **WASHINGTON WATER POWER** system, designers were able to increase the capacity for a given physical size of unit and to reduce maintenance costs on hydro electric generators.



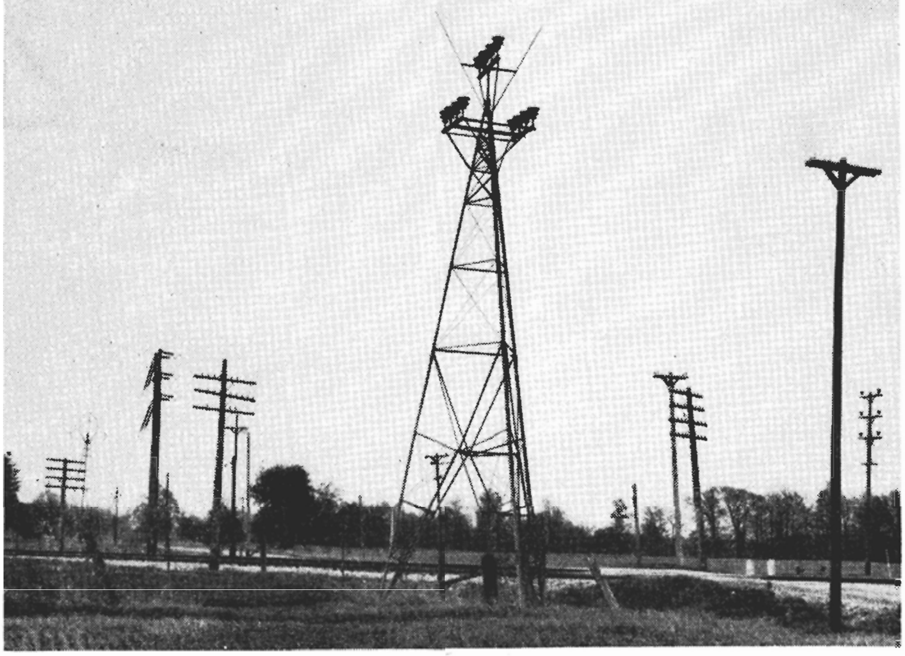
One of the largest installations of the Kaplan type units, at the Safe Harbor Station of **SAFE HARBOR WATER AND POWER COMPANY** on the Susquehanna River. The seventh unit was being installed when this picture was taken, bringing the plant capacity to nearly 300,000 hp.



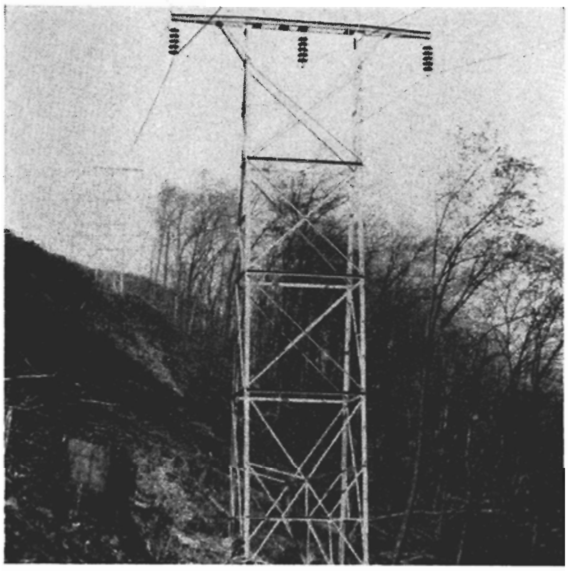
The development of adjustable blade turbine impellers greatly increased plant efficiency. The initial U.S. installation of this type of unit was made at the Lake Walk plant of the **CENTRAL POWER AND LIGHT CO.** on Devils River in Texas in 1929. Its rating was 1350 kw.

**1931. PUGET SOUND POWER AND LIGHT** first harnessed the Columbia River with its Rock Island Plant located below Wenatchee, Wash. Four 16,667 kva units, driven by adjustable blade turbines, were installed. Although the plant is designed for an ultimate of ten units, no additions have been made since 1931 because the Federal Government took over the development of the river at Bonneville and Grand Coulee.

# Transmission Line Pioneering

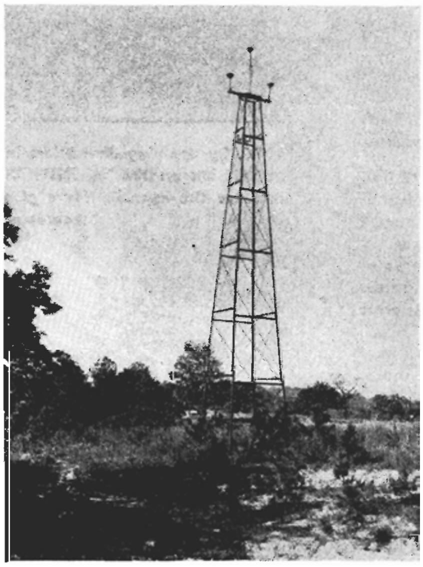


**Interesting view of 1907 steel tower construction on the CONSUMER POWER CO. system. Note the use of four pin type insulators in series as a substitute for modern suspension dead-end at railroad crossing. In the background will be seen improvements in tower top construction (rebuilt in 1914) using suspension insulators.**



*Photos courtesy of U. S. Steel Corp.*

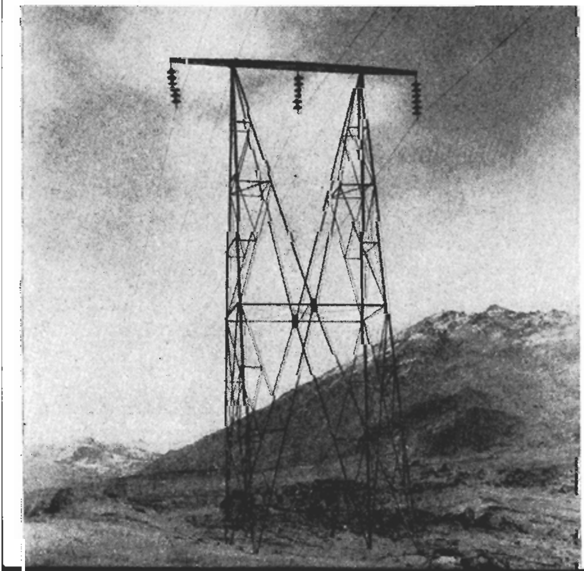
**1908. Above — second step in the evolution of steel towers. This 66 kv line uses the wedge type steel structure with two vertical extensions for ground wire.**



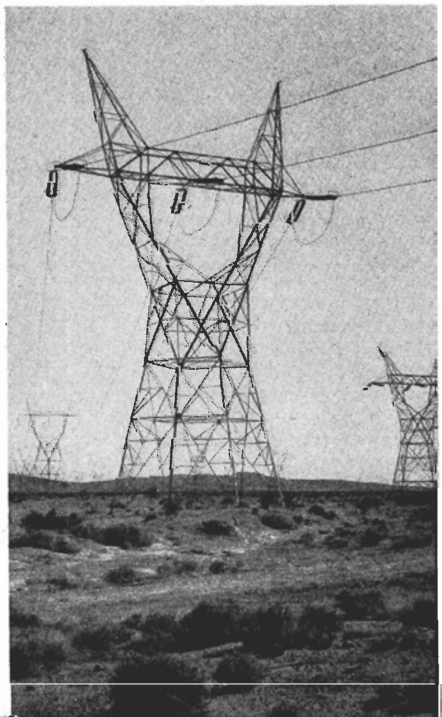
**1905. 38 kv. single circuit steel tower built by predecessor of the GEORGIA POWER CO. in 1905. This line remained in service several decades.**

POWER transmission has had a marked effect on overall system development. In the earliest days many and varied ideas concerning the proper voltage, frequencies and number of phases had to coalesce into a degree of uniformity before rapid development of the art could occur. The first plant, of necessity, had to resort to single phase transmission, because polyphase systems were not then available. When they did become available, considerable controversy developed over the respective

**1910. Below — one of the pioneering long distance transmission lines in the U. S. built by the MONTANA POWER CO. from Rainbow Falls to Butte. Great distances on this system involved early (1915) use of spark radio for communication between hydro plants.**

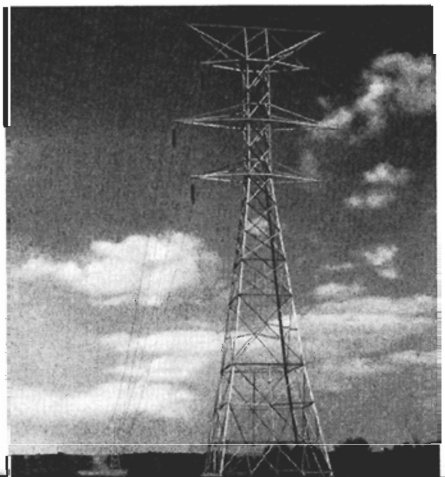


**Right—Twisted waist, single circuit tower design for the 287 kv Boulder Dam-Los Angeles circuits, the highest voltage in use at present. Each circuit will carry over 200,000 kw of power.**



**Below — modern steel tower design for high voltage transmission circuits showing offset vertical configuration of phase wires and lateral ground extension support to give correct shielding.**

*Courtesy of U. S. Steel Corp.*



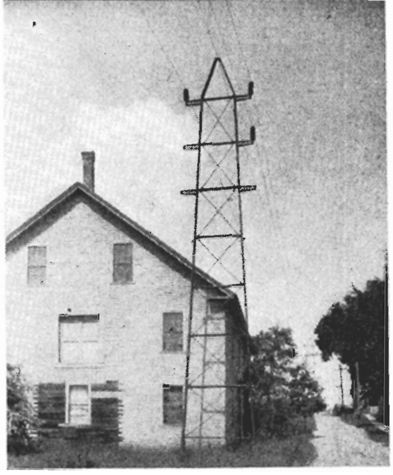
merits of the two- and three-phase systems. This matter was resolved quickly by a transformer connection which permitted interconnection between two- and three-phase power circuits, and thereafter the three-phase system, because of its great copper efficiency, became universally accepted as a standard.

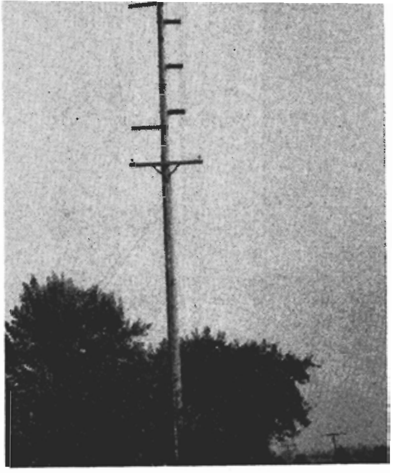
The problem of a standardized frequency was not as easily settled and prior to 1900 systems could be found with frequencies from 25 to 125 cycles. Eventually, however, 60 cycles was almost universally adopted as being the best compromise. It is to the credit of the early pioneers that the three phase, 60 cycle system was adopted as a standard early in the development of the industry and that this standard was adopted from border to border and coast to coast within a very few years. The greatest benefit of nation-wide uniformity in electrical operating systems accrued to the customer because the economy in manufacture of utilization devices is reflected in lower costs and because of the interchangeability of parts, machines and even plants over the entire area of the U. S.

Transmission lines, themselves, provide the important functions within the system of transmitting power from distant plants to load centers, and of interconnecting both generating stations and systems to the end of maximum reliability and economy of power production. Early transmission line designers, utilizing available materials, naturally selected the wood pole, crossarm, and some form of a ceramic or glass insulation as the component parts of transmission line structures. Solid copper, iron, or aluminum conductors were all that were available at the time. Up until the early 1900's, wood pole structures were practically universally used.

With the development of the suspension insulators, in 1908, voltage ceilings were lifted above the 60-kv limit of the pin-type insulator. Primarily, to obtain increased clearances and greater transmission reliability for the larger blocks of power that could be transmitted over higher voltage lines, the steel tower was designed, the development of which is shown in the accompanying photographs. Higher voltages and longer spans resulted in additional problems for the line designers. To the ever present problem of lightning protection, were added such matters as corona losses, conductor vibration, patrolling and maintenance efficiency, and the balancing of performance against economy.

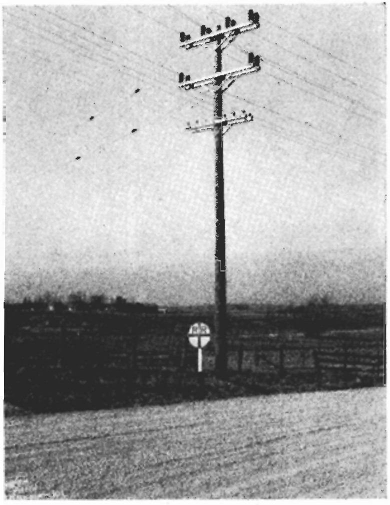
In the early days, attempts to shield line conductors from lightning strokes by means of ground wires, were not particularly successful primarily because of lack of knowledge of light-





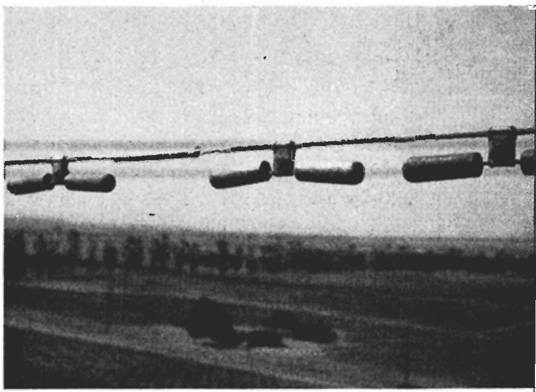
*Photograph Courtesy of Lapp Insulator Co.*

**Above — Post type insulators increased the clearance on this 66 kv circuit of the PUBLIC SERVICE CO. OF NEW HAMPSHIRE which was changed from suspension to post type in 1933, using the original steel structures. Above right — interesting 69 kv structure design using no cross-arms with conductors supported on post type insulators mounted laterally. Note how overhead ground wire is carried down the pole. CENTRAL ILLINOIS PUBLIC SERVICE CO. reports an excellent availability record on this design since its construction in 1942. Right — 1935. Line post construction on 45 kv circuits of the WISCONSIN POWER & LIGHT CO.**

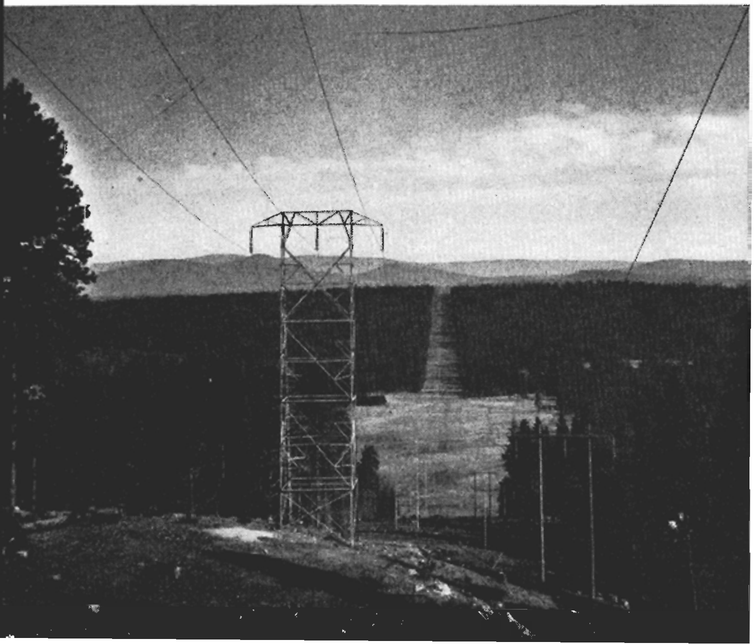


*Photograph Courtesy of Lapp Insulator Co.*

**Wind conditions, causing conductors to vibrate, resulted in fatigue failures on the early high voltage stranded cable transmission lines. George Stockbridge, transmission superintendent on the SOUTHERN CALIFORNIA EDISON CO.'s system designed this damper, which bears his name, in the middle 1920's. The result is that vibration has become a minor matter for line designers.**

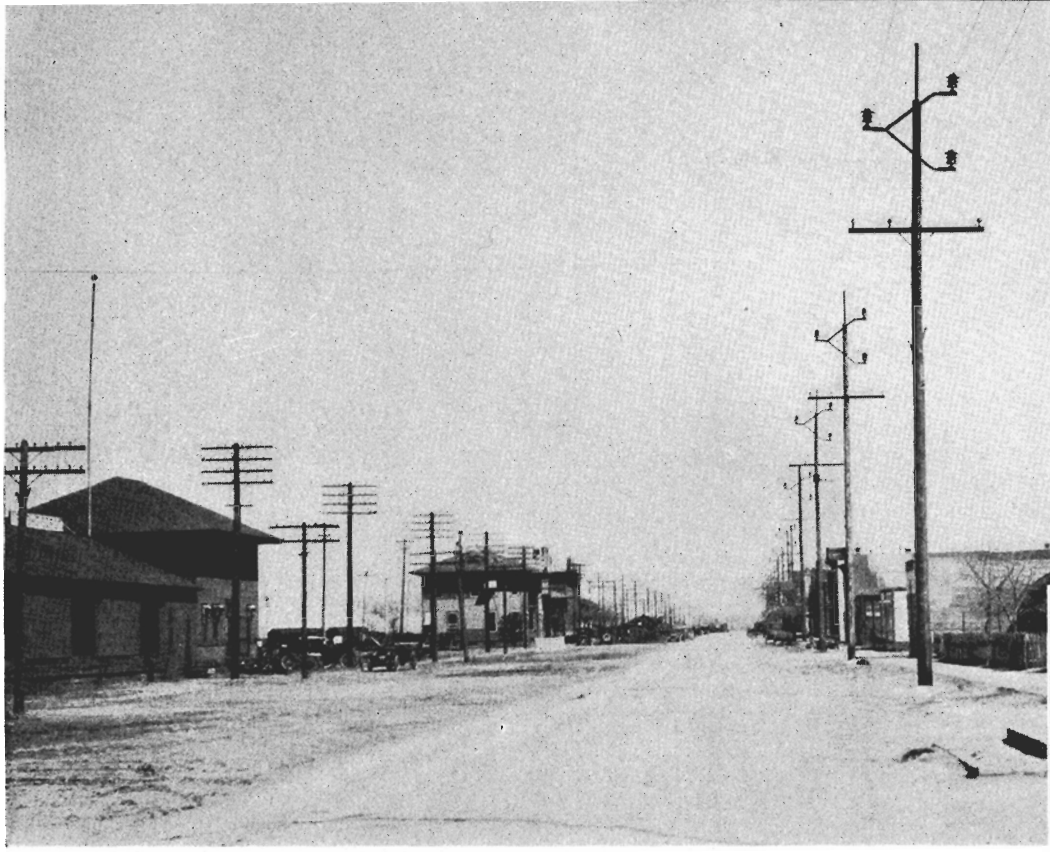


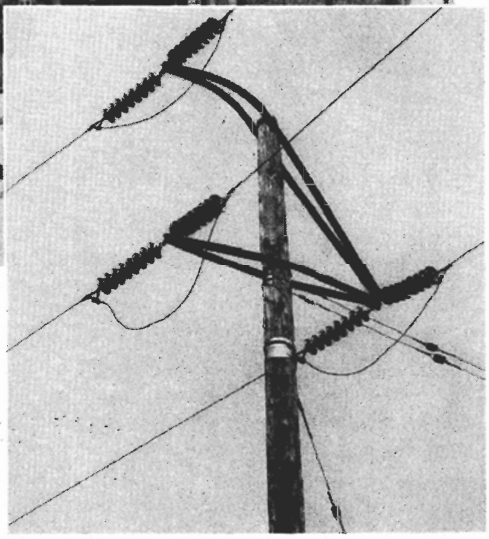
**1923. 220 kv circuits from the Pitt River development of the PACIFIC GAS & ELECTRIC CO.'s transversed 202 miles to bring power to the San Francisco area. View provides interesting comparison between 220 kv circuits on steel tower and wood pole structures, the latter being developed for high voltage circuits in the '20's.**



**1925. High strength conductors (copperweld) make possible long span construction which is particularly economical in rolling country. This 4,300 ft. span across the Cheat River in West Virginia is on the system of the MONONGAHELA POWER CO. Of the five conductors, two are normally used for telephone communication, but a transfer strain bus permits use of these telephone conductors as power conductors in case of emergency.**

*Photograph Courtesy Copperweld Steel Co.*



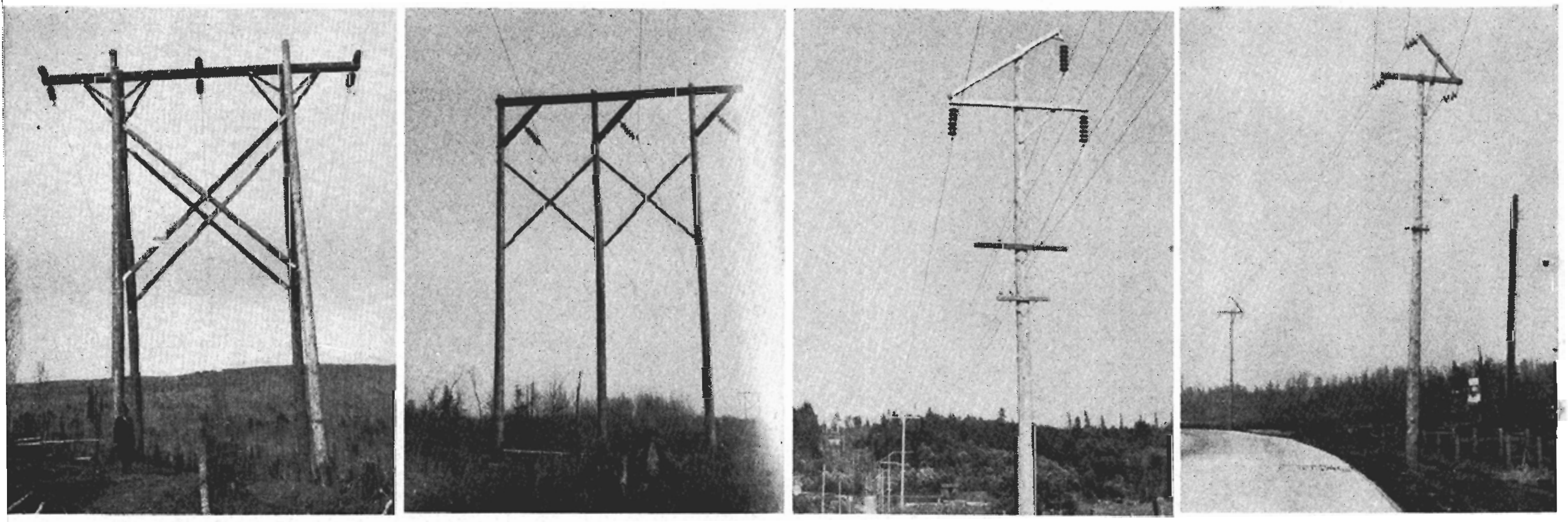


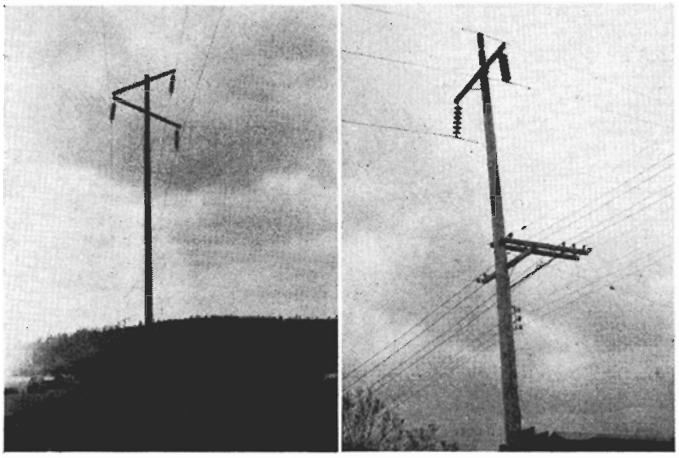
**Above** — combination wood and steel structures were tried out by early line designers. Above is a steel wishbone cross-arm, mounted on a wood pole carrying a 13 kv circuit. On the wood cross-arm below is a primary circuit for local distribution. The photograph was supplied by the **FLORIDA POWER & LIGHT CORP.**, the circuit with the configuration shown having since been rebuilt. **Right** — another design using the steel wishbone construction for 110 kv on the Kerchoff-Merced line on the San Joaquin Division of the **PACIFIC GAS & ELECTRIC CO.** erected in 1921. These designs represent attempts to keep structure costs at a minimum consistent with good operation.

*Courtesy of Ohio Brass Co.*

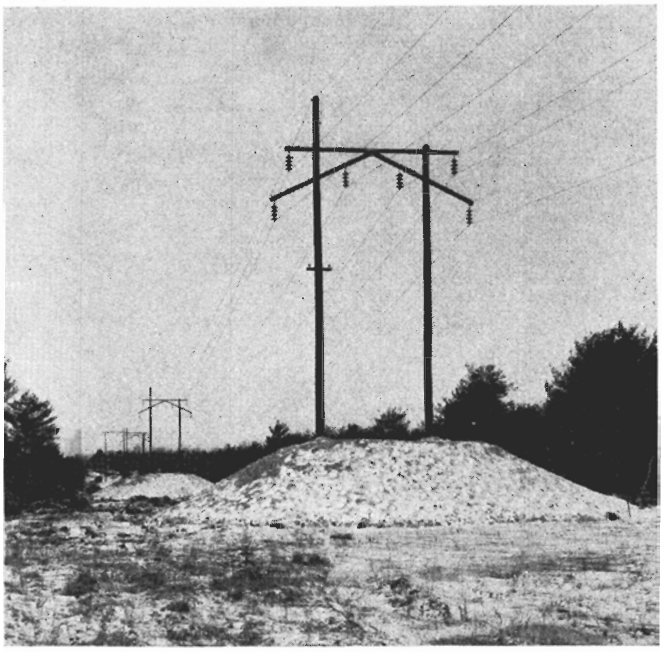
ning phenomena. Both the power companies and the manufacturers expended considerable time and effort in the study of lightning strokes. In these studies, the Wallenpaupack-Siegfried 220-kv line of the Pennsylvania Power & Light Company, placed in service in 1925, was an early field laboratory for lightning investigations. In these studies the klydonograph, the cathode ray oscillograph, and the magnetic surge recorder were helpful and widely used in field investigations. As a result, effective

**Lower Right** — Wood pole supporting structures for high voltage circuits gained popularity in the 1920's. The two views (at the lower left) of an 88 kv line of the **LAKE SUPERIOR DISTRICT POWER CO.** show tangent and angle structures for heavy loading conditions. This company was a pioneer user of carrier current communication over high voltage circuits, initiating operation of carrier current in 1921. **Lower Right** — two views of early wooden wishbone construction on the **PUGET SOUND POWER & LIGHT CO.**'s system. At the left is a standard wishbone structure using solid cross-arms with the lower in a horizontal position. At the right is a modification which gives increased vertical clearance by mounting the lower cross-arm at the top of the pole and supporting the upper arm with a jib boom brace as shown. This design gives more uniform configuration and added vertical clearance.





**Two views of 110 kv wood pole construction used by the WASHINGTON WATER POWER CO. At the left is a tangent wishbone structure and at the right is an interesting adaptation using two post type insulators in tandem as a pinnacle support for one phase conductor. These structures were used within the city where a good appearance and a symmetrical line was desired. This structure is also of interest as carrying not only the 110 kv transmission circuit but also a 13 kv primary circuit (on the cross-arm) and a 110-220 secondary (on the rack) below.**



**"K"-type wood pole structure of the NEW ENGLAND POWER CO. carries two high voltage circuits, an interesting example of the flexibility of modern wood pole design.**

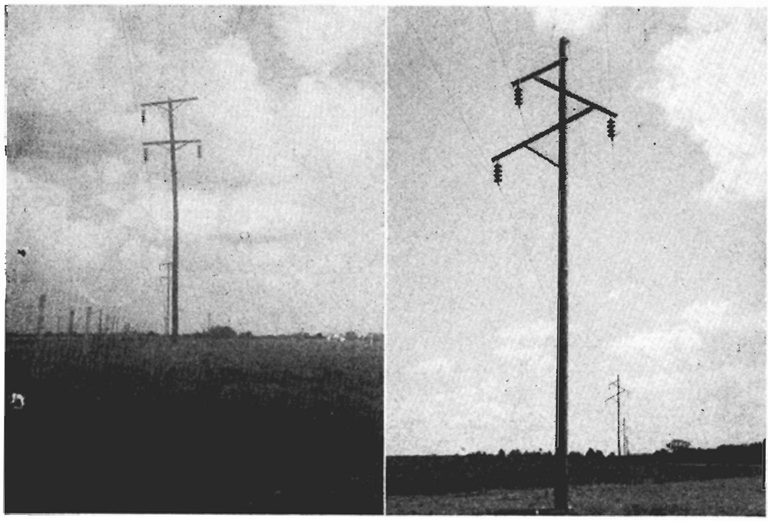
lightning protection for transmission lines has been developed (1) through the correct location of ground wires to adequately shield power circuits, (2) the lowering of tower footing resistances, (3) and the general overall coordination of insulation of the structure. In this connection, wood structures for high voltage circuits have been used extensively within recent years. Studies of the proper bracing and anchoring of the latter type structures has resulted in the development, by the manufacturers, of specialized hardware and accessories which permit great flexibility of design.

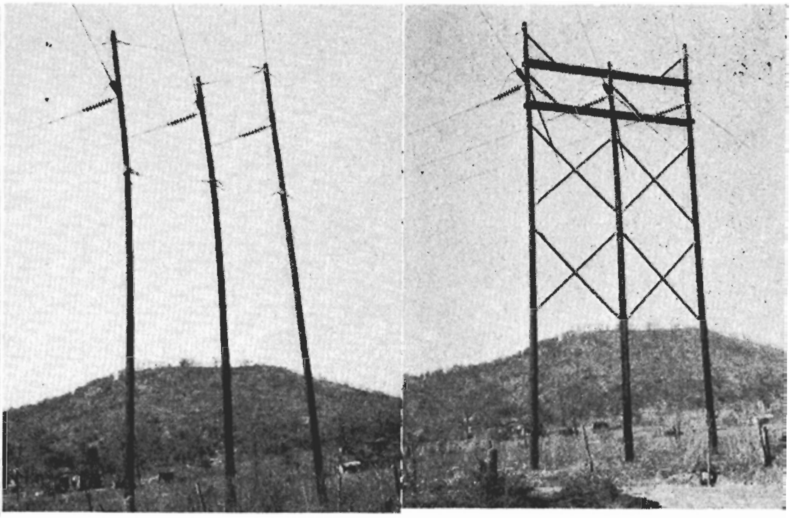
The problems of corona losses which brought attendant radio interference troubles, were met by providing new types of conductors giving the necessary outside diameters without accompanying increases in weight of the material. The aluminum cable, with a stranded steel core center (ACSR), the stranded copper conductor spun around a twisted copper I-beam, and the type HH conductor (consisting of segmented sections of copper mortised together to form a self-supporting hollow cylinder) are three of the designs produced by the cable manufacturers to meet the electrical requirements of high voltage transmission. Conductor vibration, caused by certain wind conditions and resulting in fatigue in the strands of the conductor, was materially reduced by the use of dampers clamped to the conductor near the points of suspension.

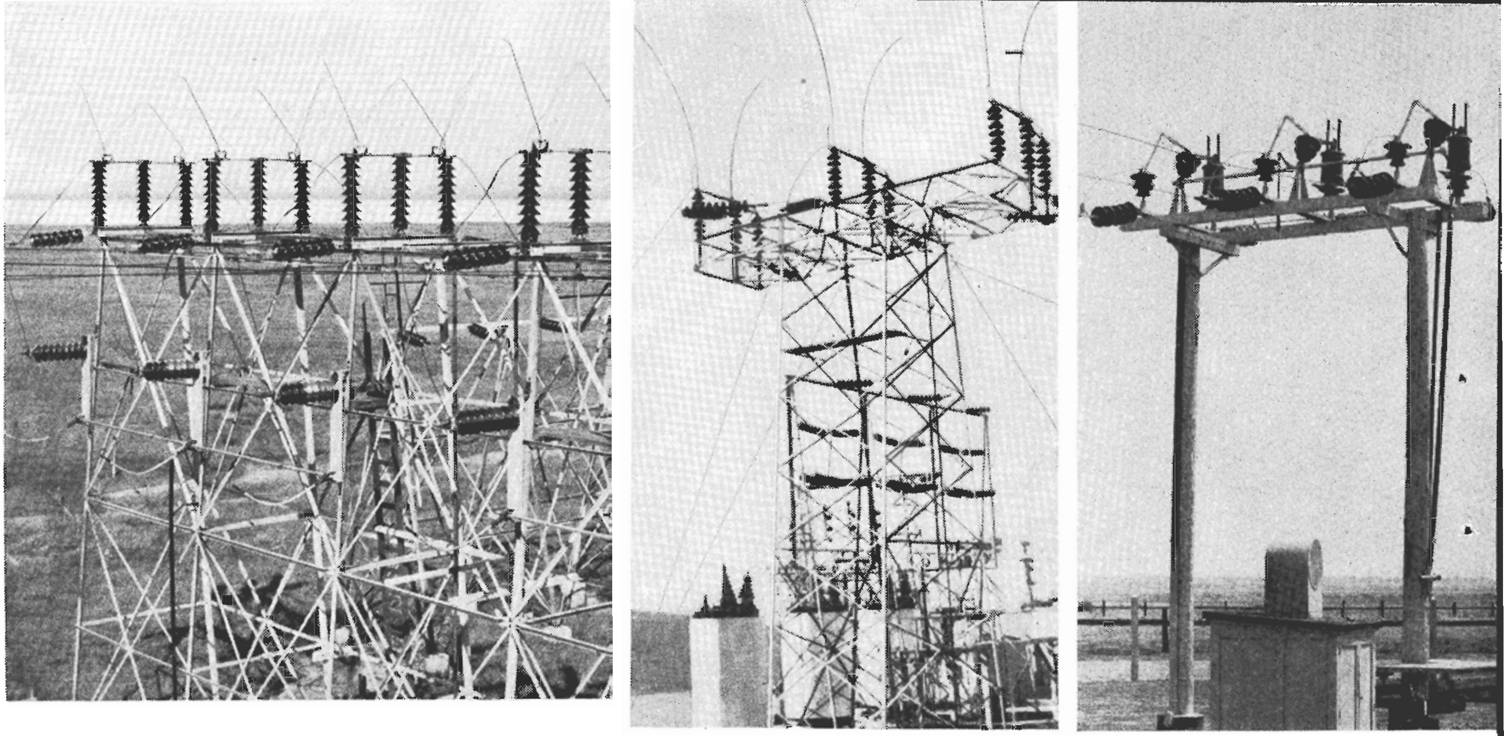
Insulators likewise have been subject to continuing improvements. On early lines, pin-type insulators were supplied in two or more parts and cemented together in the field to form a single unit. Improvement in manufacturing processes has provided the industry not only with stronger insulators with far better electrical characteristics, but also has provided special units to meet unusual operating conditions such as those encountered in corrosive atmospheres and along the seaboard.

**Lower Left — Single pole 69 kv construction in the '20's and today. Note the deflection and crossarm tilting from eccentric loading in the early view on the left. The modern design (right) provides excellent protection from the ground shield wire, ample separation for conductors, and better distribution of load on the pole. Lower Right — The old and the new in wood pole angle structure design. Both structures were designed to accommodate a future circuit. At the left poles were deflected nearly 30 degrees from their original setting. At the right, the same structure was rebuilt and strengthened through the use of modern wood bracing, greatly improving its appearance and adding the necessary strength to take the second circuit.**

*Photographs courtesy of Hughes Brothers, Inc.*



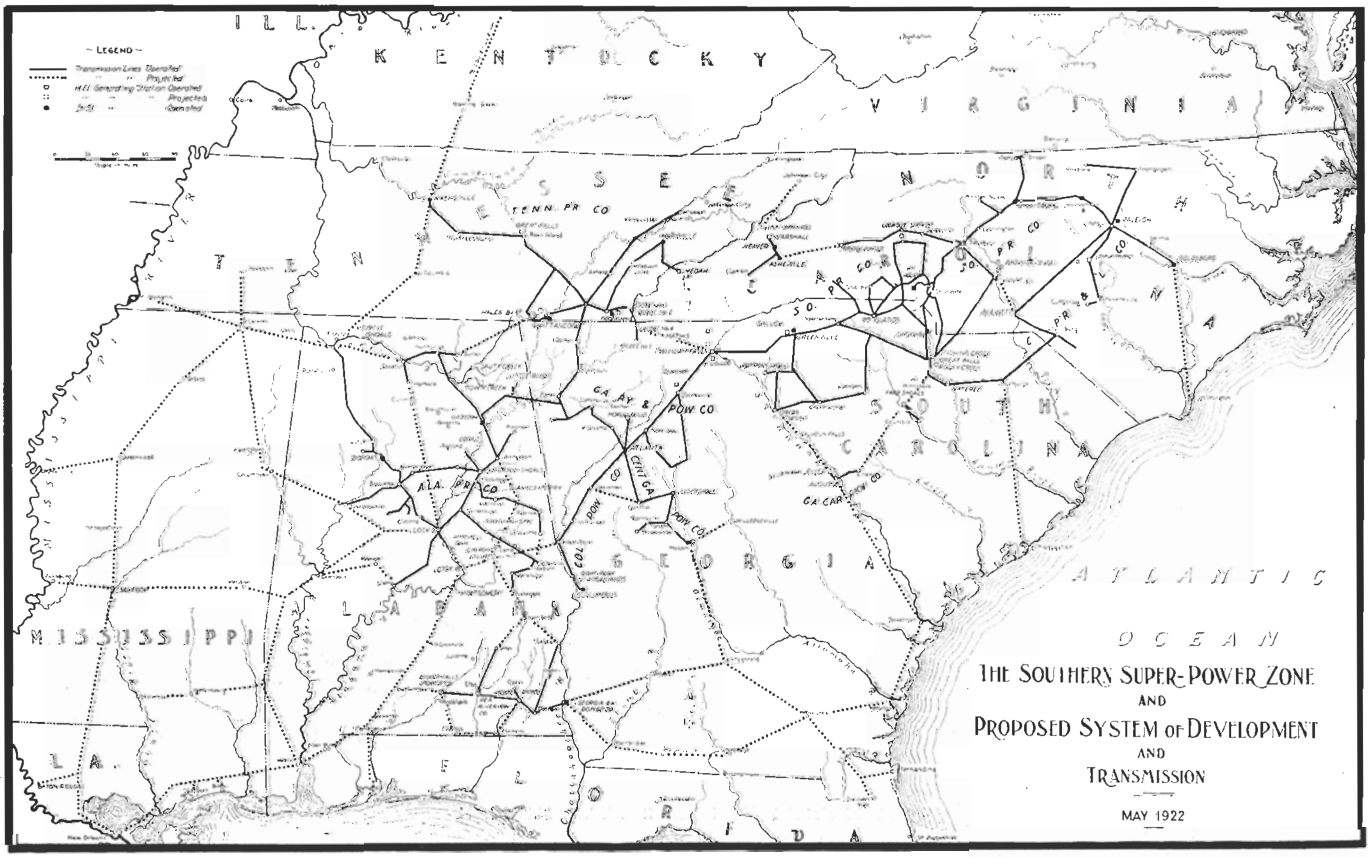


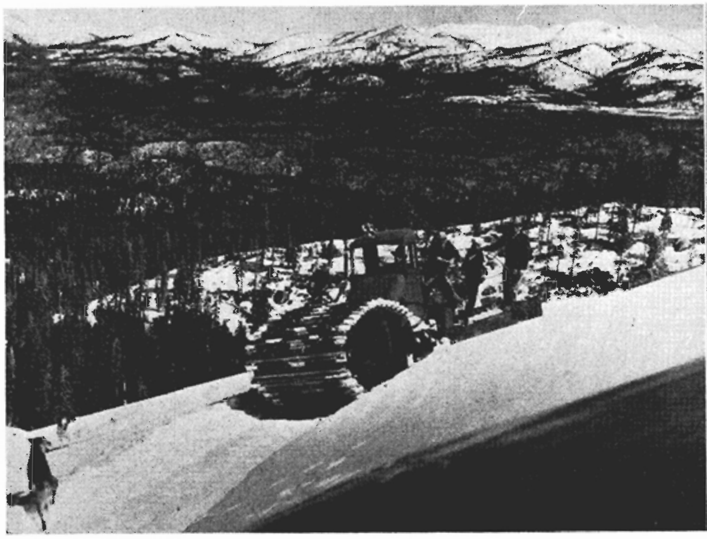


**In the early days of the industry when circuit interrupting devices were not fully developed, interruption of line currents could be effected with high voltage air-break switches. On long, comparatively lightly loaded transmission lines, interruption of charging current was a primary factor. Above are two views of the type of horn gap air-break switches used in those days. At the extreme left is a view of the horizontal break-switch used by PACIFIC GAS & ELECTRIC on its 104 kv system in 1911. Center — a vertical break horn gap switch on the CALIFORNIA ELECTRIC POWER system, at about the same time. Right is a combined oil and air-break switch for 60 kv operation, introduced about 1920. The latter device filled a need for interrupting heavier load currents, the arc starting in the oil pot shown and being drawn up through the oil and into the air for final extinction. It represented a trend to conserve investment costs by combining the two functions of circuit interruption and circuit disconnection into one device.**

Standardization of transmission line design has enabled system designers to make maximum use of interconnection as a means of increasing reliability and gaining production economies. As a result, a vast network of transmission lines has spread, during the past quarter century, to every inhabited area of the country, making power available in large quantities at almost any point. This transmission network proved to be particularly important in meeting the heavy power demands of World War II. Large areas of the country served by many power systems operate as one. For example, one vast power pool covered that section of

**System interconnection for economy and reliability was practiced by the power companies long before New Deal Power Authorities were dreamed of. This map of the planned program of electrical integration of companies in the southeastern area of the U.S. is dated 1922 and indicates the far-sighted planning characteristic of the power industry from its very inception. Incidentally, the growth of the interconnected systems shown here in the ensuing 20 years provided a major link in the great transmission network extending from New England along the Atlantic Seaboard and across to Texas. This vast transmission system proved to be an indispensable factor in the war effort as it provided ample supplies of energy where and when needed for victory.**



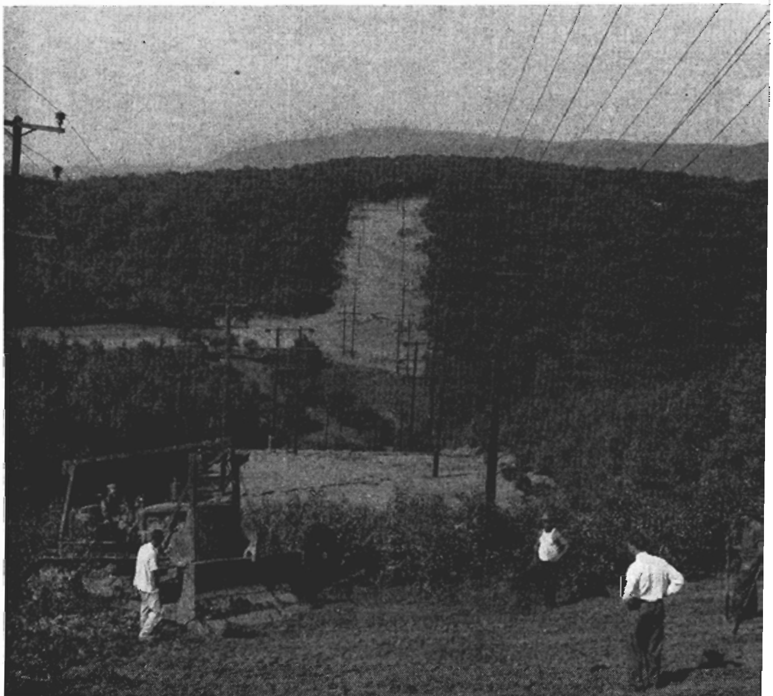


**High line patrol and movement of supplies in mountainous areas requires highly specialized equipment, such as shown here. The two pictures at the top are the "snow-mobile" and the "sno-cat" employed by the SOUTHERN CALIFORNIA EDISON CO. Right — "ski-jeep" used by the PUBLIC SERVICE CO. OF COLORADO. Equipment like this is often called upon for humanitarian purposes, such as the rescue of stranded winter sport enthusiasts and the feeding of herds caught in mountain blizzards.**

the country east of the Mississippi River and extended to the Southwest. Another blanketed the five northwestern states and still another covered the California-Arizona area.

In peace time interconnections permit power production engineers to take advantage of diversity in time (between time belts), diversity in the stream flow between water sheds, diversity in industrial demand between various sections and diversity between peaks on individual systems which make up the component parts of the power pool. Indirectly, customers benefit not only because their service is not dependent on a relatively few power sources but also because these diversities conserve system investment. They permit lower generating reserve requirements and the development of large, high efficiency base load plants at points in the intersystem area where greatest production economy can be attained.

**Transmission line patrolling and maintenance is an important function in achieving trouble-free service. Below left — the MONTANA POWER CO. since 1925 has been using airplanes to patrol high lines traversing the Rocky Mountain area. The two men on the right of the group are Harry McCann, superintendent of the Missoula Division, and Ralph Barnes, sub-foreman. Below right — modern mechanical equipment, such as the bulldozer shown, is used to keep transmission line right-of-way free of underbrush to facilitate movement of materials in case of an emergency and to avoid fire hazards to the line. This view was taken on the system of the PENNSYLVANIA POWER & LIGHT CO. Chemical weed killers also are now being used to assist in keeping down underbrush growth.**



# Cable Developments

WHILE electric power transmission was first accomplished by underground conduits, materials available in the early days precluded the successful development of the underground cable in its present form. Because gutta-percha flowed at temperatures developed in early lighting circuits, it could not be used. The Edison system, therefore, resorted to copper rods, wrapped with jute, and drawn into pipes with a bituminous compound forced in around them. Obviously, these underground circuits were both inflexible and not adapted to the higher voltages which made the a-c system economical.

Early city ordinances which prohibited overhead circuits in certain areas, plus the copper economy through the a-c system, stimulated research to find a suitable high voltage, flexible cable. In 1888 a NELA report stated: "Experience in Washington has lead to the statement that no insulation could be found which would operate two years at 2,000 volts."*

Flexibility, which permitted lines to be drawn into and removed from underground conduits without disturbing the street surface was of paramount importance from both service and economy standpoints. The need was met by the design, in the closing years of the 19th century, of conductors insulated with treated paper and covered with a lead sheath.

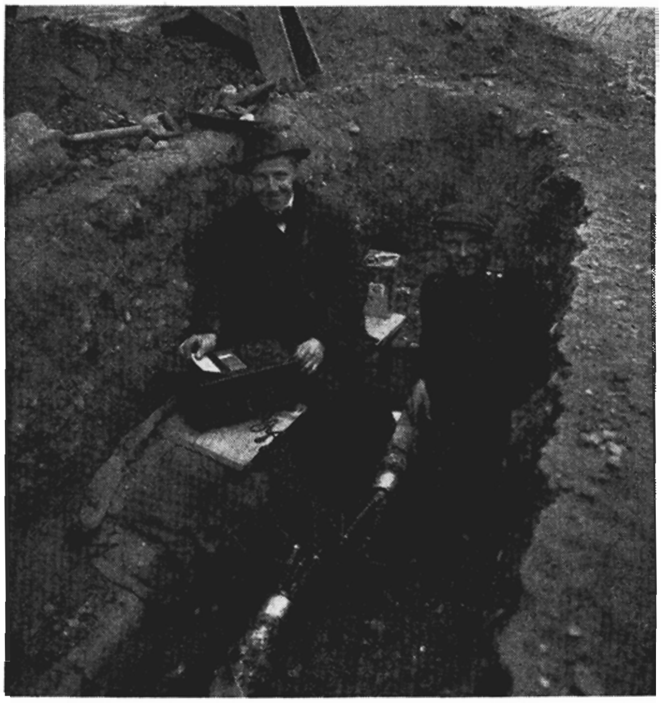
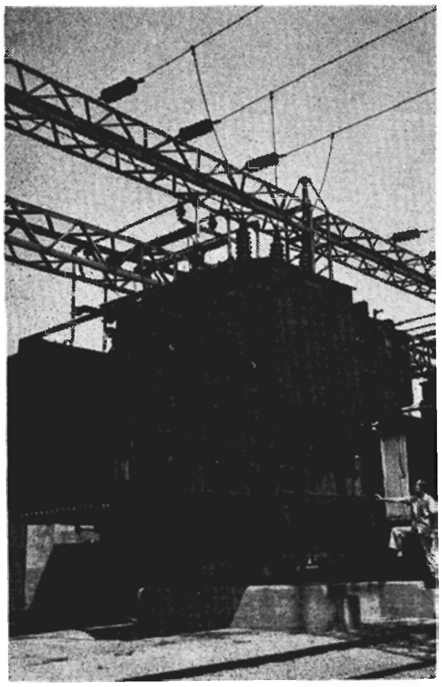


*Photo courtesy of James G. Biddle Co.*

**1914. These men in a cable trench in Boston were conducting installation resistance tests, with a "Megger", to determine the condition of the cable before making the cable splice. Similar tests, utilizing the same type of equipment, are still made today.**

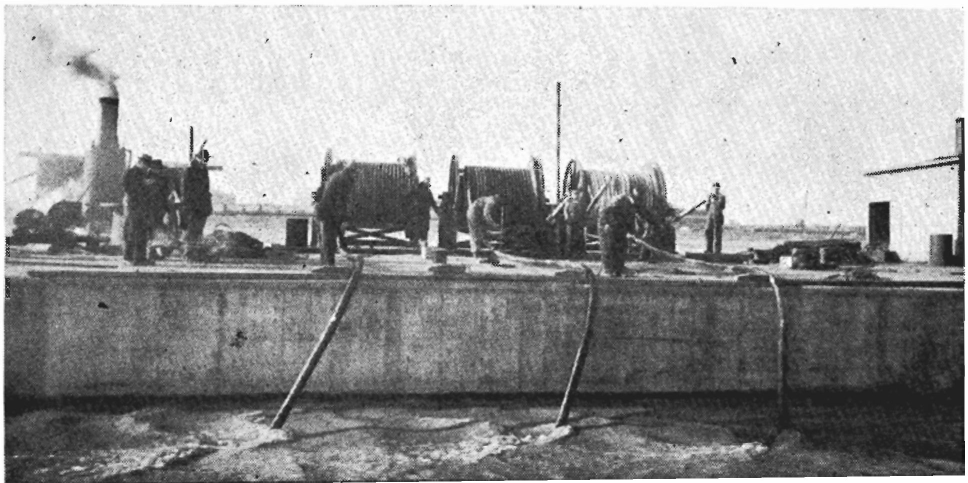


**1923. Here is one of the transformers which step-up from 11 to 66-kv for transmission through the CLEVELAND ELECTRIC ILLUMINATING COMPANY'S high voltage underground cable system. This company pioneered 66-kv underground transmission with two 66-kv cable circuits, 8¼ miles in length, in the city of Cleveland in 1923. Prior to this time, the highest operating voltage of underground cable circuits was 33-kv. This development permitted the transfer of large blocks of power from one section of the city to another, and also between plants.**

By 1921 about 5,000 miles of this type of cable had been installed in the U. S. and was operating at voltages up to 25 kv. The relative isolation of systems and the small blocks of power needed to be transmitted over areas unsuitable for overhead construction made higher voltage cable unnecessary. In the 1920's, however, plant and system interconnection made necessary the transmission of larger blocks of power and the consequent operation of underground lines at transmission voltages. This gave impetus to new cable designs for larger capacity circuits.

Significant developments of the time included the shielding of

**1926. THE UNION ELECTRIC LIGHT AND POWER COMPANY OF ST. LOUIS (now THE UNION ELECTRIC COMPANY OF MISSOURI) established a precedent in the size and length of submarine cables, installed in single lengths, with the installation of three 33-kv cables across the Mississippi River. This photograph shows the three cables being laid on the river bottom from a specially rigged barge. These armored cables were about 4¼" in diameter and 2500 ft in length. Previously, the maximum length of cable that could be manufactured was about 1200 ft, and necessitated a splice in midstream.**



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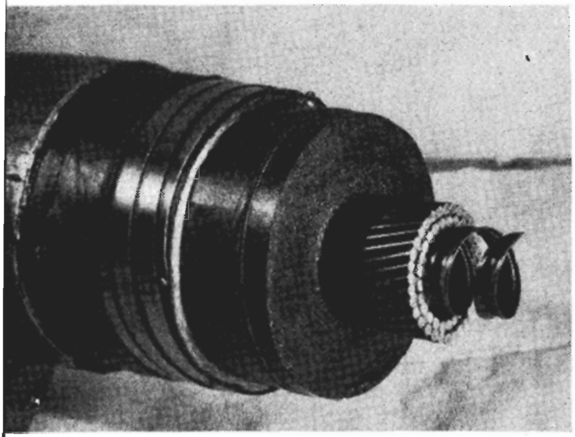
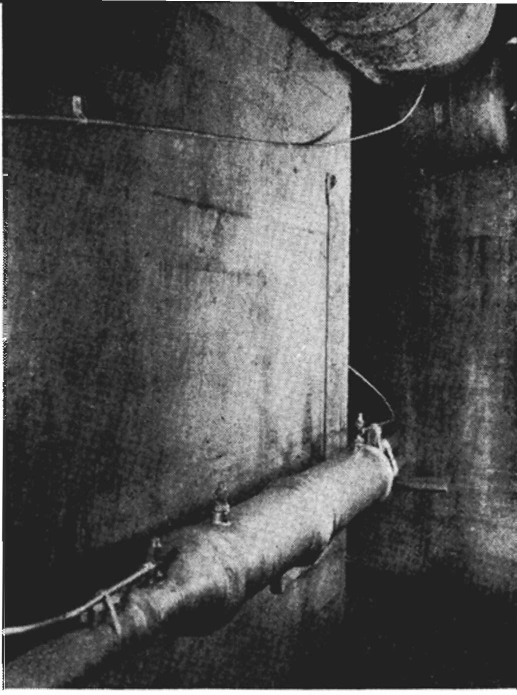
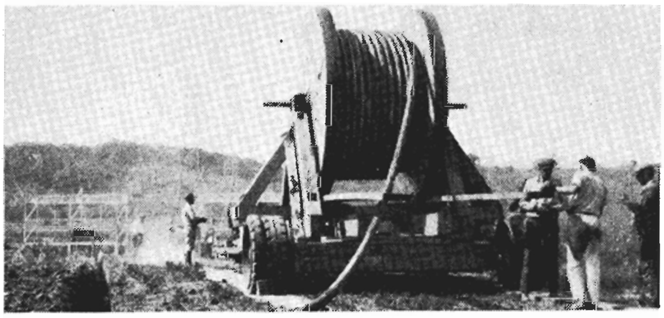
* Underground systems reference book (1937).



**1927. THE COMMONWEALTH EDISON COMPANY** pioneered in the installation of a 132-kv oil-filled, three-phase cable line, six miles in length. This cable connects with 30 miles of overhead line to form a link between this company's Northwest Station in Chicago, and the **PUBLIC SERVICE COMPANY OF ILLINOIS'** station at Waukegan, Illinois. As shown here, the cable has a single-conductor (600,000 cm) with a hollow core for the thin oil and double reinforced sheath to withstand the high internal oil pressure, maintained by means of oil reservoirs. This cable line has had no failure and has doubled the maximum operating voltage for underground cable, making it possible to transmit large blocks of power underground at this voltage without the use of intervening transformers.



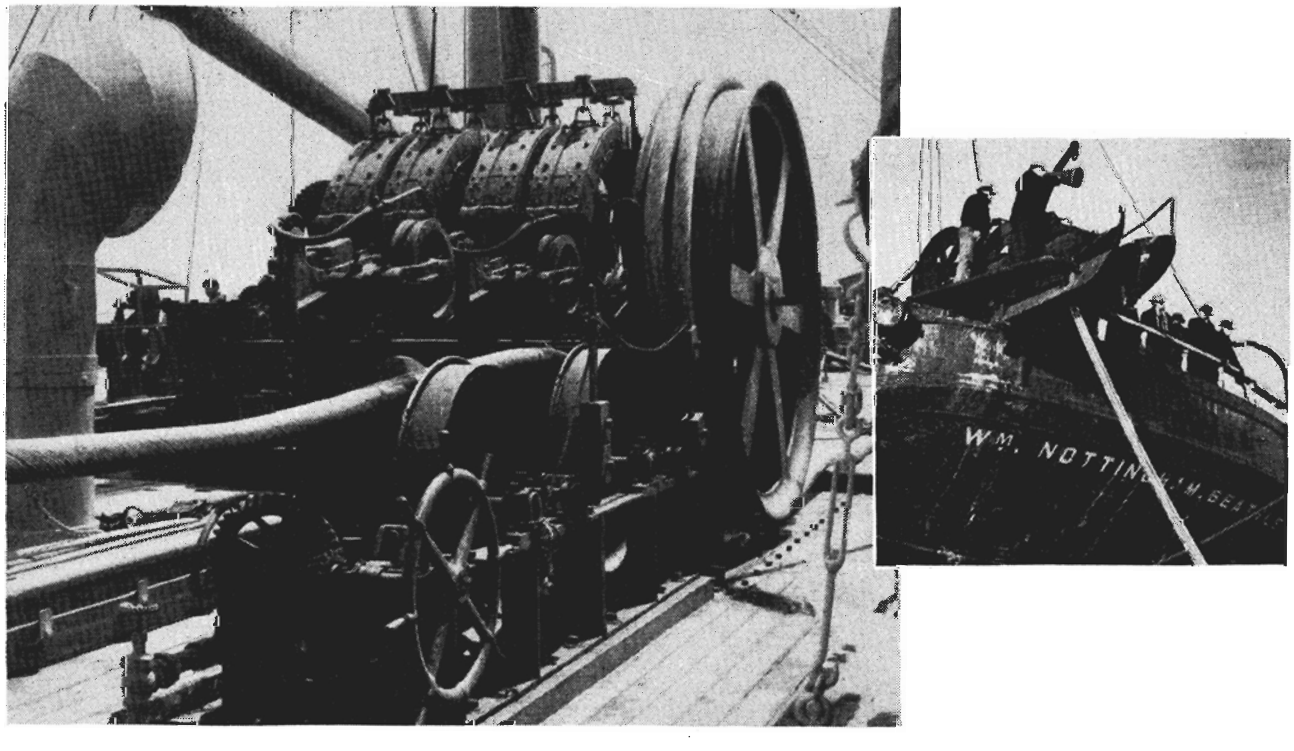
**1930.** One of the first installations of 33-kv oil filled cable was made in Syracuse, New York by the **CENTRAL NEW YORK POWER CORP.** Shown here is one of the manhole splices in this 350,000 cm cable. The success of high voltage underground cable installation depended in large part on the development of splicing techniques.

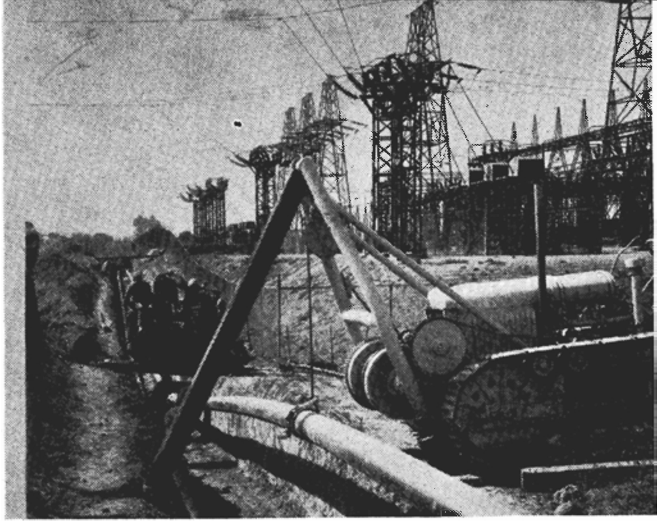


**1930. THE CINCINNATI GAS AND ELECTRIC COMPANY** installed the pioneer 3-conductor, oil-filled, 75-kv underground cable line. This cable was armored and was installed directly in trenches, as shown here, without the use of ducts. This practice materially decreased installation costs.

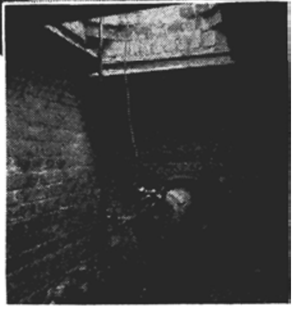
individual conductors (to prevent internal corona), the use of liquid or nearly liquid saturating components (to fill in voids where ionization of air might develop), and the application of reservoir systems to maintain internal pressure of the dielectric. In 1923, a 66-kv cable circuit had been installed by the Cleveland Electric Illuminating Company. By 1926, 132 kv circuits were being operated by the Consolidated Edison Company of New York and the Commonwealth Edison Co., Chicago. These latter installations were of the single conductor type and used oil alone as the saturating compound. The oil was conducted through the length of the cable by means of a hollow center tube.

**1940.** Shown here is the aft of the **PUGET SOUND POWER AND LIGHT COMPANY'S** cable ship, laying a power cable across Puget Sound. Also shown is the special cable-handling equipment installed on the deck of the ship. The success of submarine cable installations contributed to the establishment of dependable large capacity power transmission across waterways which formerly offered a formidable barrier.

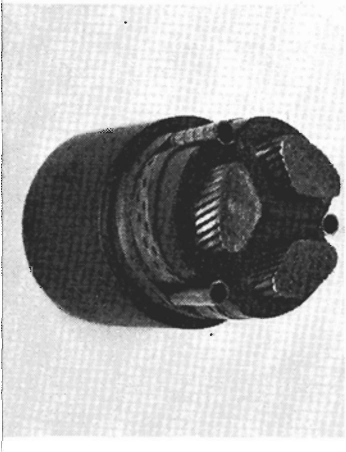




**1932. PHILADELPHIA ELECTRIC COMPANY in 1932 completed the pioneer installation of an Oilostatic high oil-pressure cable transmission system at its Plymouth Meeting Substation. The circuit consisted of 6,000 feet of 750 mcm and 1000 mcm single conductor cable with 0.375 in. impregnated paper insulation. For 15 years this 66,000-volt circuit has demonstrated the stability and service reliability of such high voltage paper-insulated cables installed in a welded steel pipe line and maintained at 200 lbs oil pressure. The proved economy and failure-free record of such systems has lead utilities to purchase over 70 circuit miles of this type cable for 15 major installations during the past 18 months. Engineers have found that high oil-pressure cable systems are particularly applicable for underground transmission systems between heavy load centers or near central and substations as economical alternatives to difficult overhead construction or right-of-way problems. For generator and transformer leads at central stations, this system is being used to save space, conserve copper and avoid awkward construction.**



**1941. This 120-kv cable line, of the steel pipe, nitrogen pressure type, connects a 75,000-kw turbine unit to a bus seven miles away. The other view shows the method of connecting pressure and gage to the pipe line. This type of installation facilitates the transfer of the output of a major unit on DETROIT EDISON'S system direct to the center of power distribution.**



**1938. Installation of a low pressure, gas-filled cable by the CONSOLIDATED EDISON COMPANY OF NEW YORK, INC., was the first underground cable installation to provide continuous supervision over the lead sheath of the cable, as well as the joints and terminals. The cable is filled with dry nitrogen gas maintained at a pressure of 10 to 15 lbs psi. A pressure relay sounds a signal when the pressure drops below nine lbs. This system insures maximum continuity of service.**

**1946. One of the longest underground high voltage cable installations on record is being completed by the NEW ORLEANS PUBLIC SERVICE, INC., to form the high voltage transmission loop on its system in New Orleans. This cable line, 59,000 ft in length, utilizes three single-conductor, paper insulated, 600 mcm, 100-kv cables in 6⅝" in diameter steel pipe, filled with oil at 200 lbs operating pressure. This view shows the cable rig feeding the cable into the encasing conduit at one of the manholes. Completion of this high voltage transmission loop will effect savings in system operating economies and contribute materially to the continuity of power supply to the New Orleans metropolitan area.**

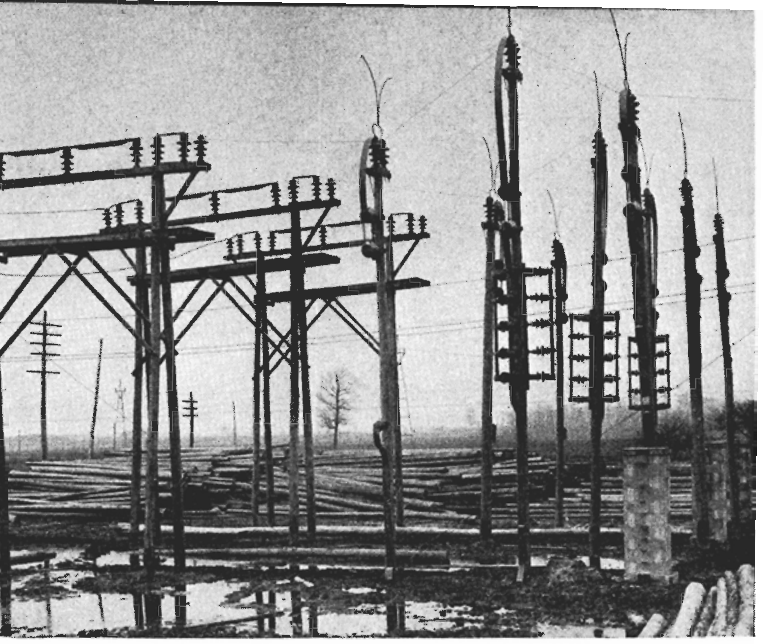
Three-conductor, oil filled cables, in which oil tubes were carried in the interstices between conductor segments were introduced in 1930 with a 75 kv installation by the Cincinnati Gas & Electric Co.

Cable runs are generally carried in ducts with terminals and joints made in manholes. In the late 1930's a further development to improve cable performance utilized iron pipe ducts in which the cable was drawn, the duct being subsequently sealed and filled with nitrogen under pressure. This system provides pressure control on the cable from outside the sheaf and is used for important, high-capacity underground tie-lines. A similar system using oil instead of nitrogen as the pressure medium is also used.

Cable developments also have permitted submarine installations, a particularly valuable contribution where water distances would have been a formidable barrier to overhead construction. In such installations the cable is generally given the extra protection of wire armor over the lead sheaf. For river crossings, laying operations are generally accomplished from barges with the cable laid in trenches dredged in the river bottom. On especially long runs, such as across bays or inlets, special cable laying ships are used.

The satisfactory installation and operation of high voltage underground cable circuits has presented many problems to the manufacturers and power company engineers. Special tools, equipment, and apparatus have been required; careful operating records have been necessary to determine the causes of trouble and possible remedial measures; and new installation techniques have had to be developed. The art of underground power transmission has been developed in the past quarter century and, with higher load densities and increasing urban congestion, it is likely to continue to provide a fertile field for continued progress.

# *Lightning Protection*



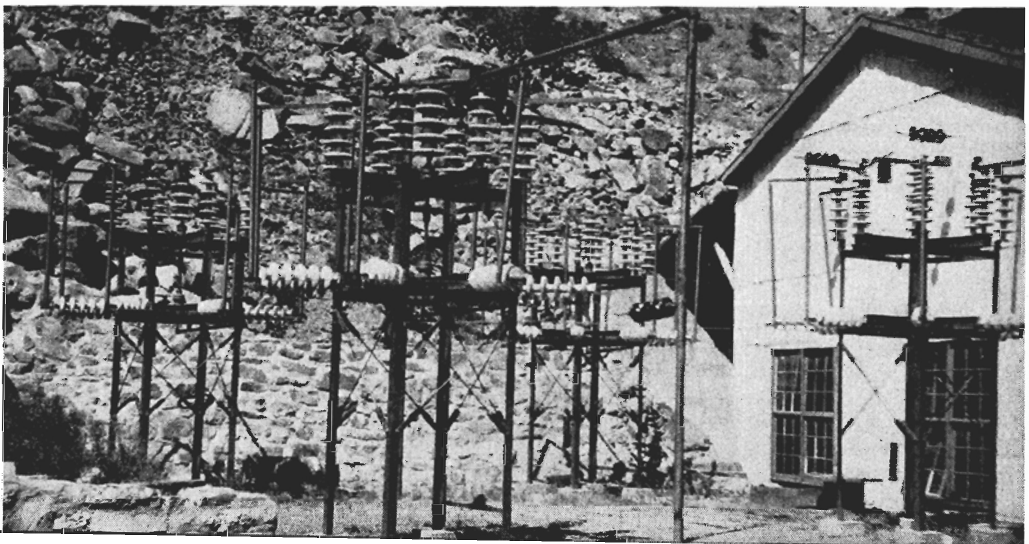
**Protecting transmission lines from lightning strokes was an early and continuing problem for transmission engineers. Above — the 60 kv lightning arresters used in 1907 on the NIAGARA-HUDSON system. These arresters consisted of three multiple gaps each connected to ground. The 7-in. lowest setting gap was grounded through a concrete block resistence. The 9-in. intermediate gap was grounded through carborundum rod resistence and the longest gap (12-in.) was grounded to a buried copper plate. Left — unusual photograph of lightning stroke forming the background for a transmission line in Oklahoma.**

DURING the past quarter century, power transmission systems have grown tremendously in complexity. Voltages have doubled and trebled, line lengths have greatly increased, and interconnections have become more extensive. Knowledge of how to protect against system disturbances due to lightning and other causes has grown rapidly, and both system calculation and system control methods have been materially improved.

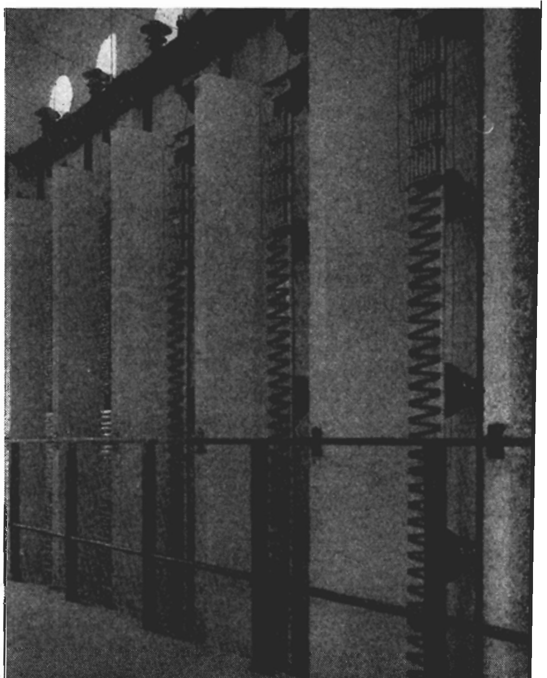
As systems have grown in extent and complication from the simple radial systems of the early 1900's to the loop and inter-

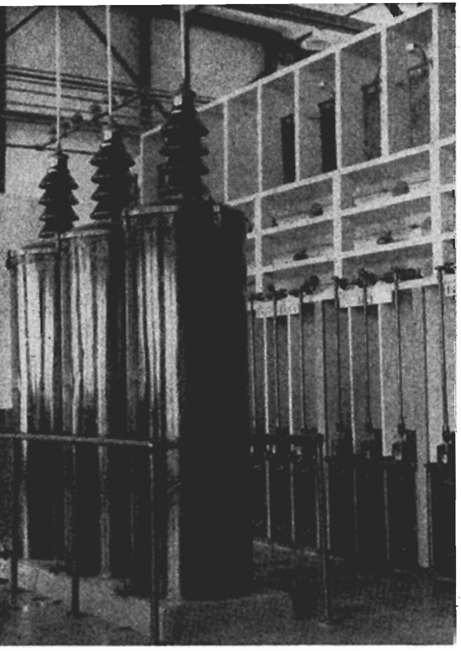
*(Continued on Page 251)*

**1910. Rare photograph of an installation of the Nicholson arc extinguisher at an early plant of the PUBLIC SERVICE CO. OF COLORADO. This type lightning arrester automatically short-circuited the phase wire through a fuse when an arc to ground occurred, the zero voltage on the line during this period theoretically quenching the arc. After the fuse blew, full voltage would again be restored for normal operations. This view shows how the apparatus functioned. The towers in the foreground mount vertical fuses which rotate in a horizontal plane between the line contacts. A magnetic switch mounted on the nearest tower structure, (one switch per phase) trips a release when the voltage to ground on any phase conductor is deficient. This permits a counterweight to turn the rotating fuse wheel and move the fuse between the contacts, thus grounding that phase through the fuse. Several operations could be completed before replacing the fuse links. An early operating report indicates that the device was not particularly successful as surges kept actuating the relay after the initial fault — and an elaborate fireworks display similar to a gigantic pinwheel could be expected.**

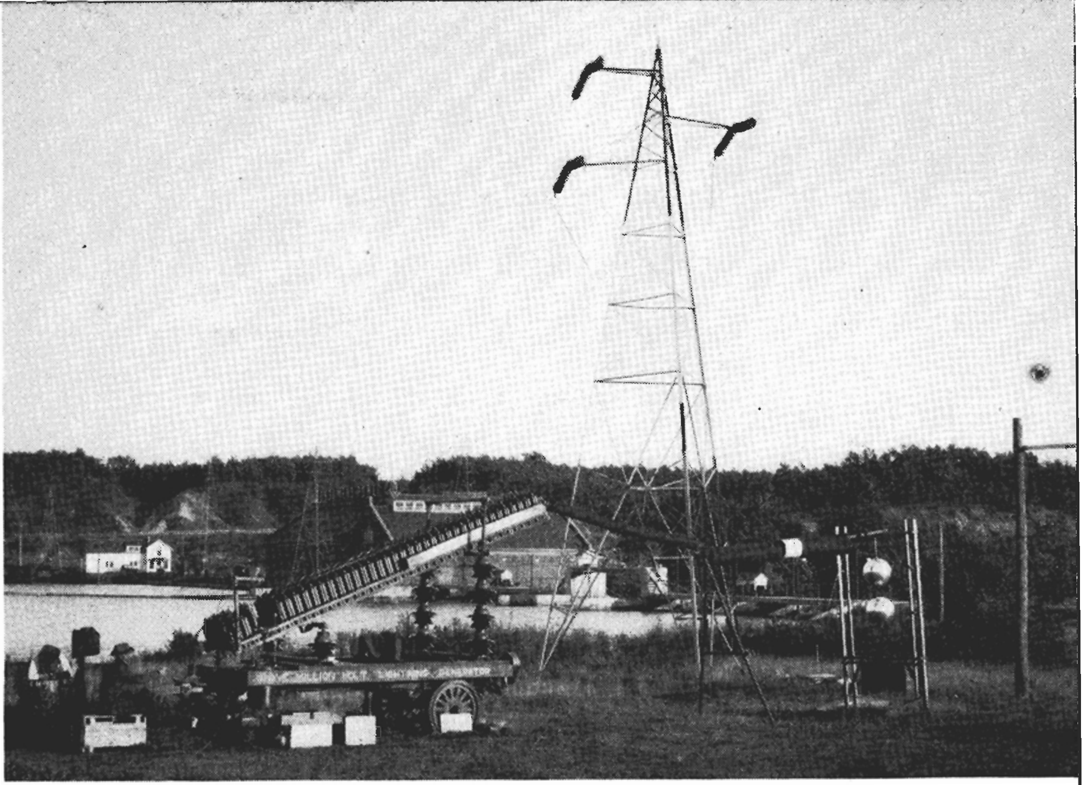


**Early 60 kv multi-gap lightning arrester of the Wurt type installed in the Post Falls Power Station of the WASHINGTON WATER POWER CO. This was one of the first types of lightning arresters developed and, while satisfactory, had the disadvantage of having to be mounted indoors.**

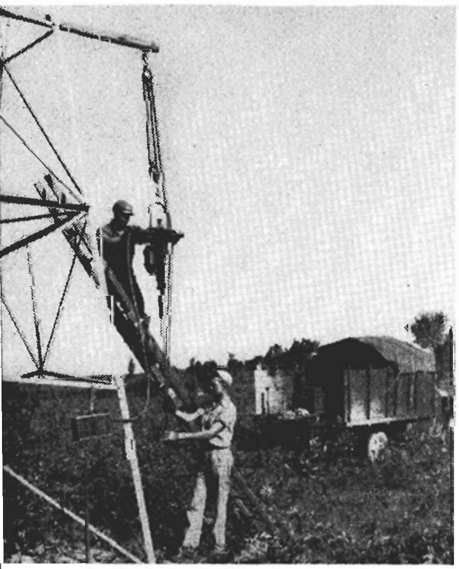


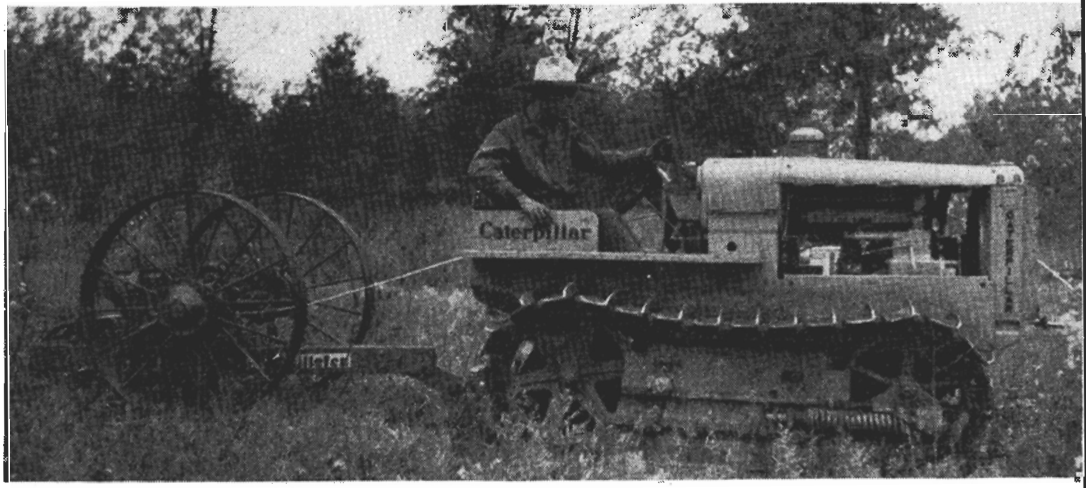


Electrolytic type lightning arrester used in an early western station was an improvement in design, but was not particularly applicable to high voltage alternating current circuits because of excessive maintenance costs.



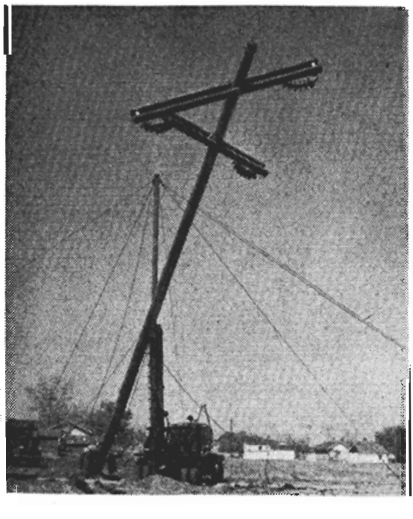
Efforts to coordinate lightning protection involved both field and laboratory studies. Collaborating with manufacturers, many power companies made intensive studies of both natural and artificial lightning in the field. This view shows a field study using a million volt lightning generator on the CONSUMERS POWER system in 1929. Here the operator is imposing an artificial million volt lightning bolt on the line.

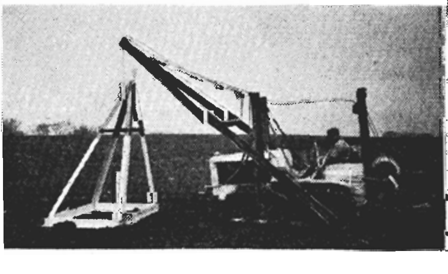


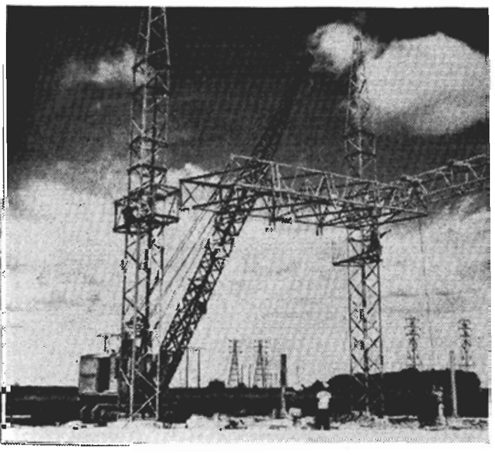


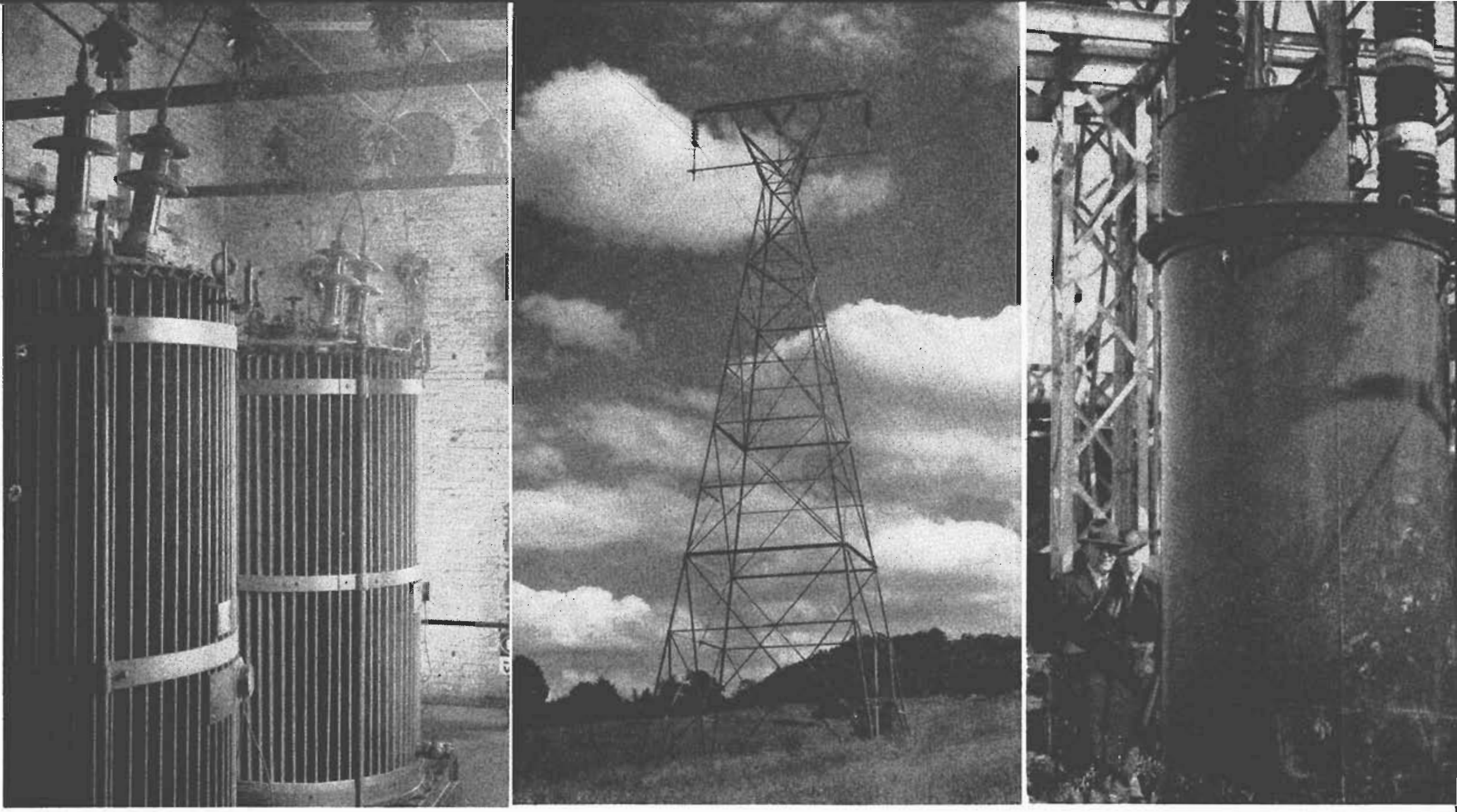
As the result of lightning studies engineers developed new theories for lightning protection. In these, the location of overhead ground wires to shield the power conductors has become one of the most important single factors in trouble free operation. To make ground wires effective, low resistance tower footings or good grounds must be obtained. At the left, modern power hammers drive a copper ground rod into the earth at the base of the tower. At the right above, a continuous ground circuit or counterpoise is sometimes necessary where low resistance cannot be obtained with ground rods. Here a tractor hauls a special plow which automatically buries the counterpoise wire, the latter being attached to the tower footing at each structure.

Modern construction equipment replaces horse and manpower to reduce costs and speed the completion of jobs. Left — a completely framed wood pole structure is being raised to position. Center — small boom mounted on caterpillar quickly sets anchor section for steel towers. Right — large boom raises prefabricated substation structures into position.









**Milestones in the protection of transmission systems against transitory faults are depicted in the views above. In the lower right-hand corner of the photo on the left is shown the first commercial application of a 44-kv "Thyrite" lightning arrester, a radically new type of protection when installed on the BANGOR HYDRO-ELECTRIC CO. system in 1929. The center view shows a pioneer installation (1932) of "De-ion" protector tubes on a 55-mile, 66-kv line of the INTERSTATE POWER CO. Constructed some years previous, this line was not provided with overhead shield wires and was subject to frequent tripouts due to lightning. Protector tubes reduced service interruptions from approximately 88 to 4.2 per 100 miles per year. On the right is shown a ground fault neutralizer installed in 1941 in an 88-kv substation of the LAKE SUPERIOR DISTRICT POWER CO. This device extinguishes arcing ground faults by effecting resonant neutral grounding of delta systems, thus eliminating the outages which would occur on an equivalent system with neutral solidly grounded.**

connected systems of today, the task imposed on the protective relay and switching equipment has become increasingly severe. Likewise, the problem of coordinating system operation has become more and more complex.

With radial systems, shorter lines and lower voltages, switching and protective requirements were a relatively minor problem. With the increases in power levels, line lengths and line voltages, system switching and protection problems multiplied. Protection against lightning disturbances became a major factor. System grounding problems required intensive study. Protective relay systems had to be developed which would promptly isolate any portion of the system on which a disturbance occurred, with a minimum of damage to equipment and minimum effect upon customer service.

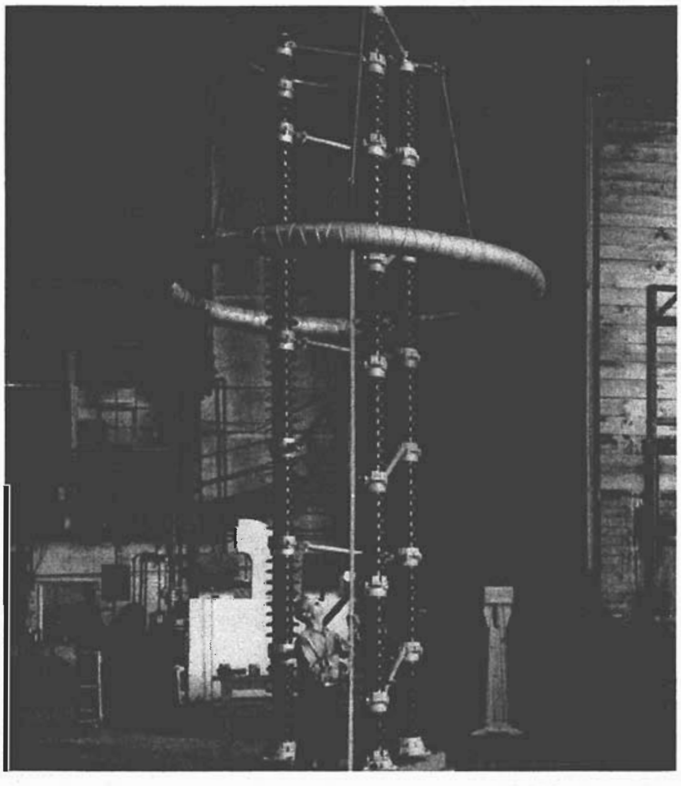
The pattern of growth first involved interconnections between generating plants on the same system and then interconnections between adjacent systems. There soon developed the problem of electrical stability between plants and between systems, which required an intensive study of apparatus characteristics as well as the layout and operation of the balance of the power system. It was found that operation of the system often was as great a factor in system stability as was the design of the system itself.

The merger of individual companies into larger groups quickly made apparent the necessity of a unified method of handling the output of widely separated plants. As a first step toward centralizing load dispatching, a central control point was established from which an operator could direct generation and transmission functions. One of the first companies to inaugurate a centralized control system of this nature was the Pacific Gas and Electric Co., which established its first central load control station in 1906.

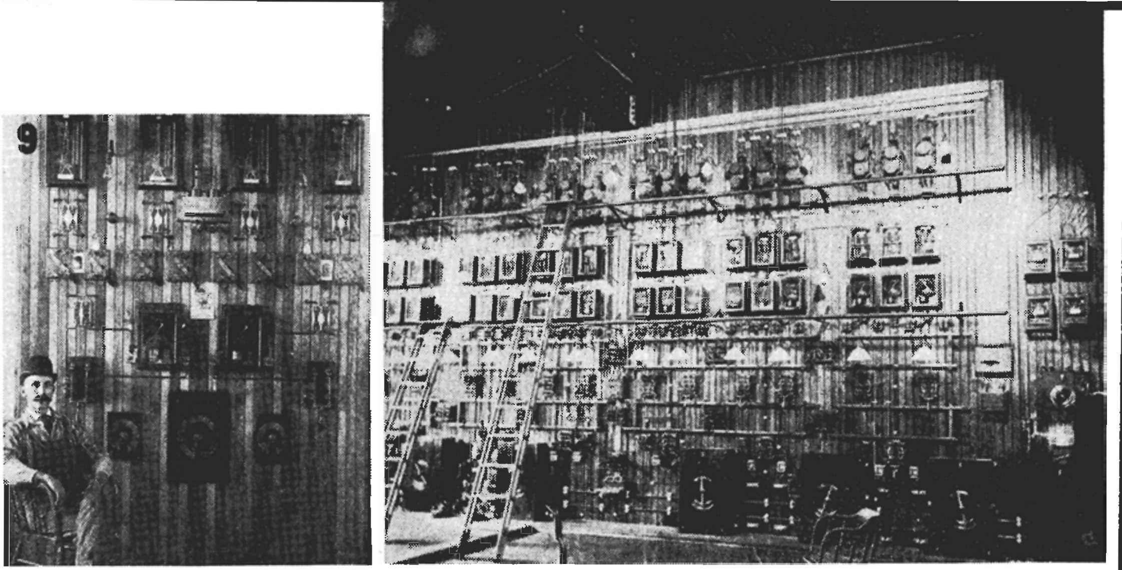
Development of the high-voltage a-c transmission line has been largely dependent upon the progress made in the study

**1947. Built to corral lightning surges which might strike the new experimental 500 kv transmission line of the AMERICAN GAS & ELECTRIC SYSTEM, this lightning arrester represents the peak of the designers art to date. This experimental 500 kv installation will explore the possibility of further economies in power transmission.**

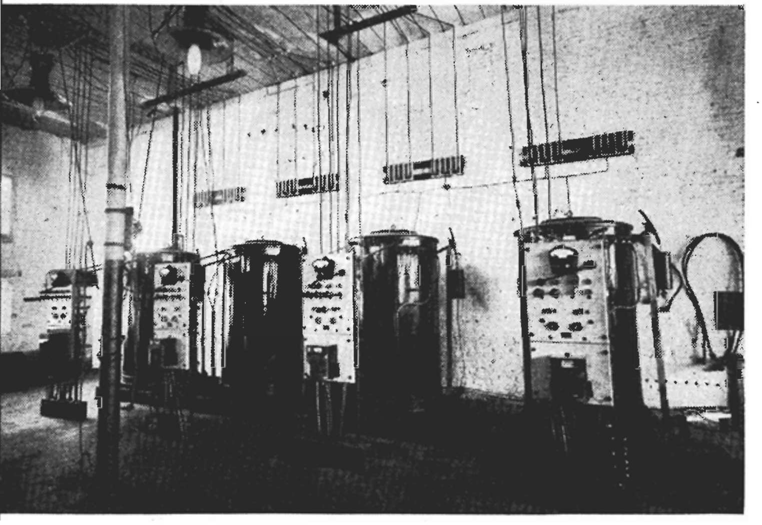
*Photo courtesy of Westinghouse Electric Corp.*



# *Switchgear, Substations and Protective Devices*



For power distribution in the early days, designers apparently sought the nearest wall—at least the pictures above would so indicate. In the view at the right of an 1100 volt board of the **DUQUESNE LIGHT CO.** in 1899 note the use of the movable ladders in order to reach the top tiers of meters and other equipment.



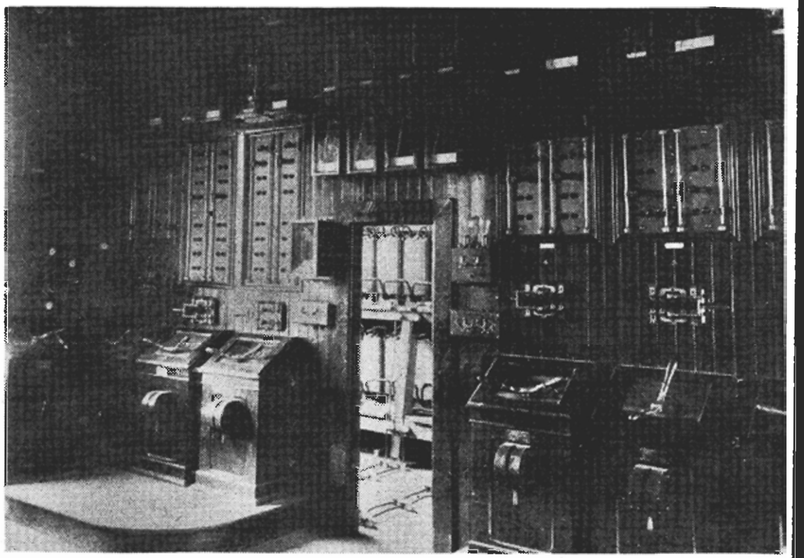
Street lighting constant current transformers and distribution panels on the **WASHINGTON WATER POWER** system at about 1903 when plugs and jacks were used to complete the circuits. Note the old style arc lamps, and the early a-c watthour meters at the base of the panels.

and understanding of the lightning problem. Such investigations were both tedious and time-consuming, but led to the development of preventive and remedial measures which have practically eliminated lightning as a cause of interruptions on major transmission circuits.

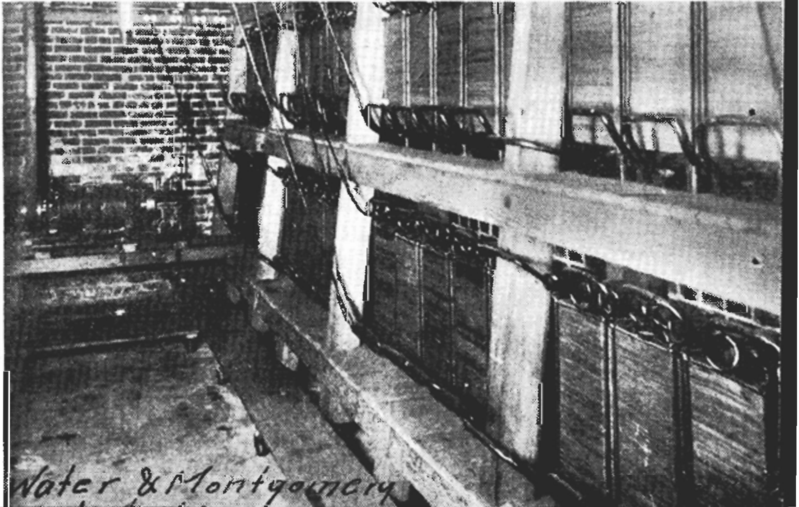
Determination of the impulse strength of the various elements of line and station equipment, and the characteristics of protective devices required, necessarily involved a great amount of testing in the laboratory and the field (see page 250). This work, carried out cooperatively by the power companies and the manufacturers, has contributed greatly to the high reliability of service enjoyed by the customer today.

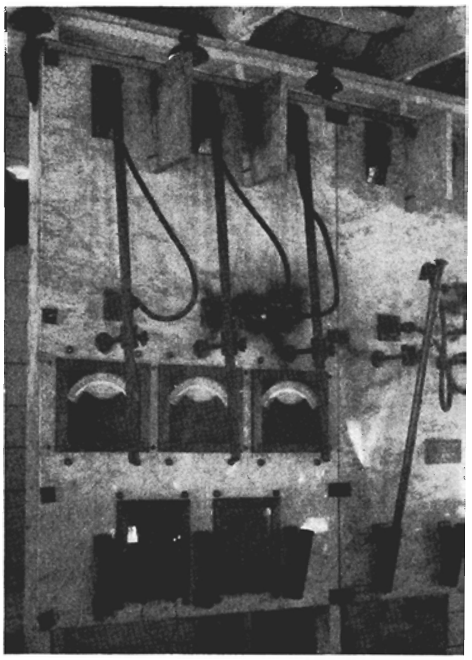
Many methods of increasing the practical operating power limits of a system were studied, with particular emphasis on the use of flashover prevention and arc suppression measures. Among the matters studied was the effectiveness of ground wires, the effect of ground resistance, and other matters important to the design of future transmission lines, stations and equipment. From these studies, it was definitely determined that properly grounded overhead "shield" wires were a valuable protection during lightning storms.

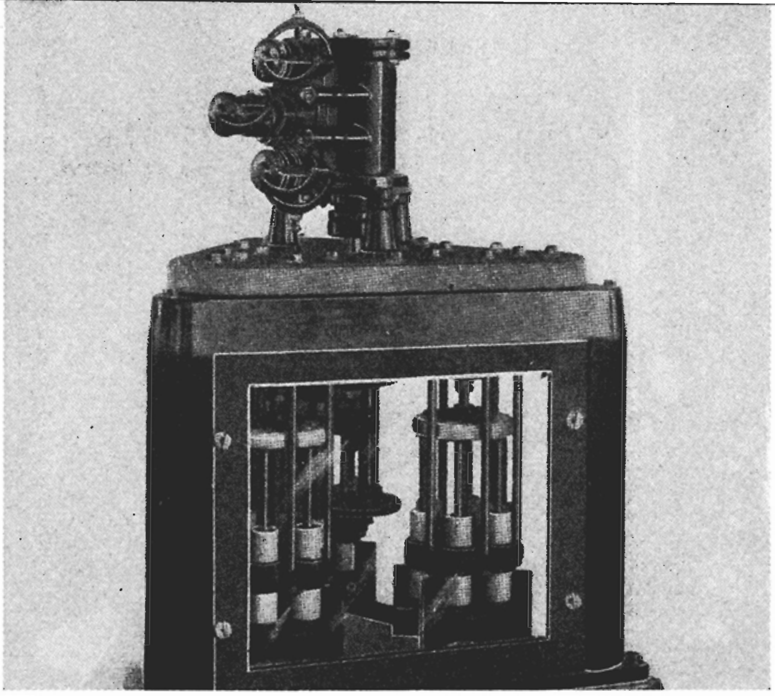
One of the most notable devices developed for lightning protection was the expulsion type protector tube. This device was



The views above and below show what is probably the first distribution substation in existence—being the terminal point for the 4000-volt transmission line from Willamette Falls to Portland, Ore., which was put in operation in 1899. Seven 125 cycle single-phase circuits were put into service. The view above shows the interior of the station with the plug boards and Stillwell regulators. The latter were manually-operated, tap-changing devices activated through the handles shown at the top of the cabinet. Each single-phase 4000 volt line terminated in a bank of 10 air-cooled transformers (at that time called converters) connected in series as shown in the picture below. The voltage of the secondary side was 1100 volts. The editors wish to thank Mr. O. B. Coldwell, retired general superintendent of the Portland General Electric Co., who furnished the information on this interesting pioneer station.







**Above left — the "buggy whip" circuit breaker and switchboard used in an early power house of the PACIFIC GAS & ELECTRIC CO. for 2,300 volt circuit interruption. Flexible leads from the power supply were attached to wooden poles and moved to the upper contacts as indicated on the left, poles being clamped into position. The "open" position is shown at the right where the pole was set into a socket mounted at the base of the switchboard. Above right — pioneer power operated circuit breaker installed in Brooklyn in 1897. It was rated at 7,000 volts and operated by an electro-pneumatic operator. Contacts were inside metal-lined porcelain cups. After numerous experiments cups were filled with oil and successful arc interruption was obtained.**

a direct outgrowth of lightning studies and has been used extensively to prevent flashover of transmission line insulators, disconnect switches, and bus insulators, as well as on transmission line towers adjacent to a station to reduce the magnitude of surges coming in on the line and thus relieve the duty on the station arresters (see page 251).

Developments in lightning arresters have kept pace with other developments in the protective field. Experience with actual lightning discharges and laboratory tests have demonstrated the ability of the modern arresters to discharge direct strokes of lightning. As a result, a better degree of protection for lines

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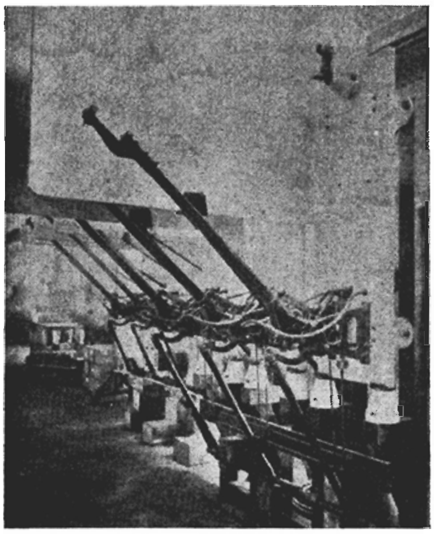
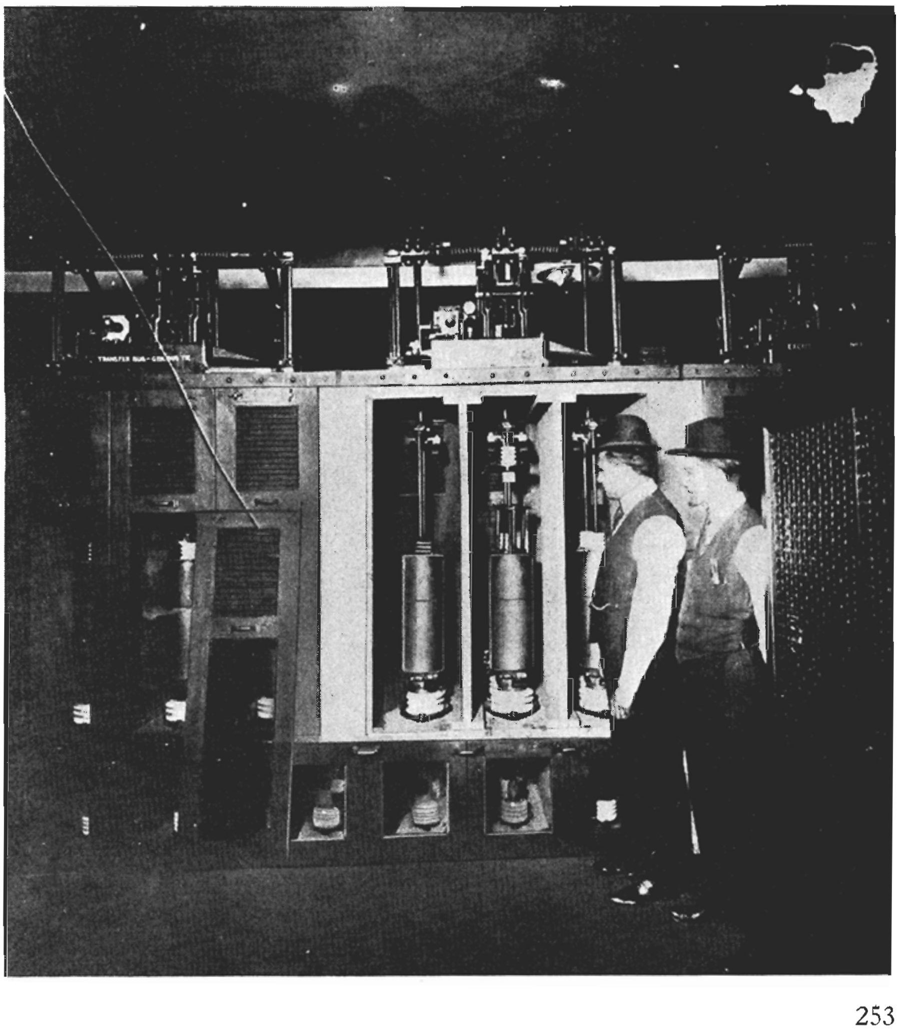
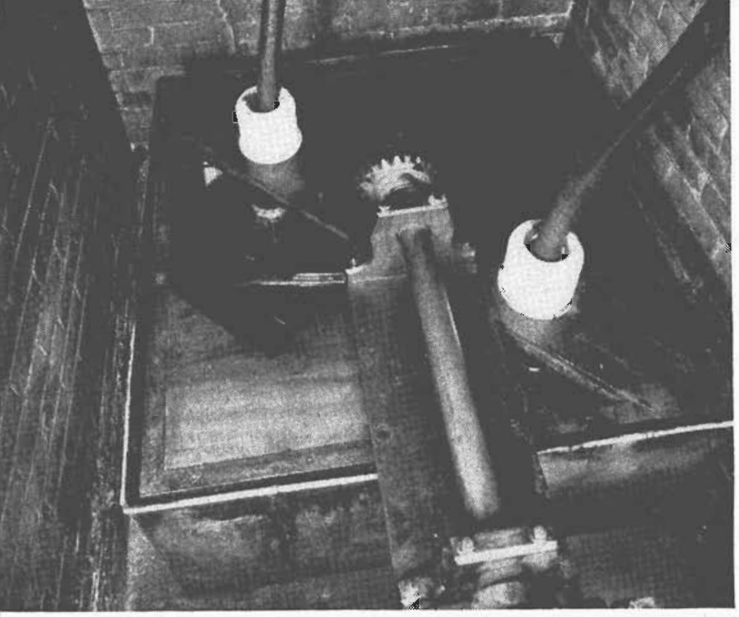


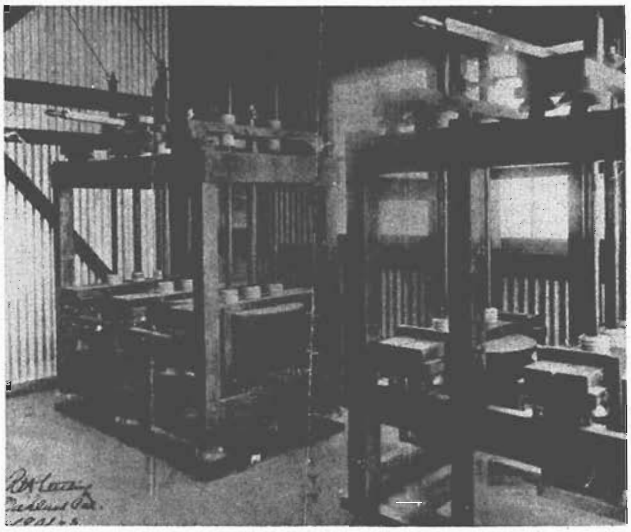
**Early Westinghouse 25 kv, three pole, pneumatically operated air circuit breaker. Note phase isolation through use of barriers. Interrupting theory involved lengthening the arc until extinction was obtained.**



**Early type "H" General Electric 12 kv oil switch installed in the Fisk Street Station of the COMMONWEALTH EDISON CO. in the early 1900's.**

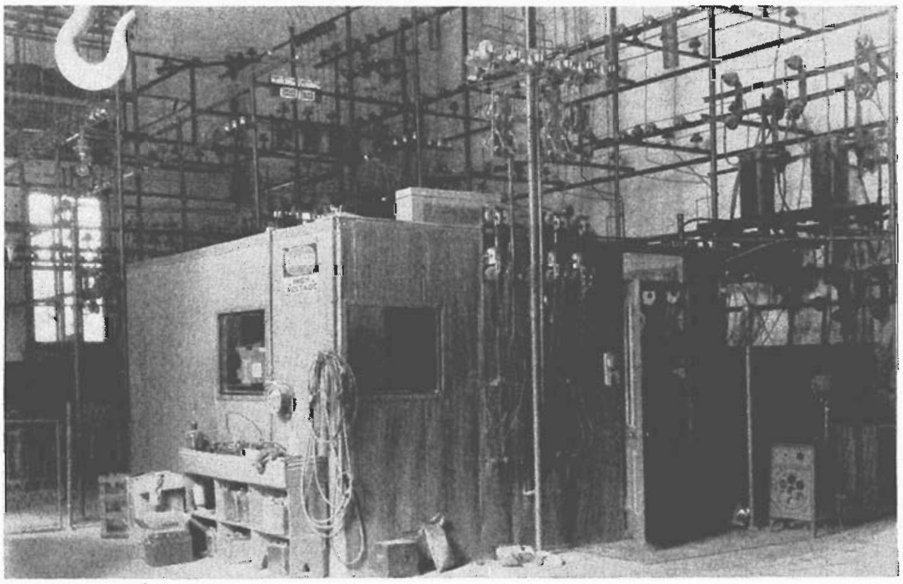


Pioneer high voltage oil circuit breaker developed by the CONSUMERS POWER CO. and known as the "wagon box" switch. Developed at the turn of the century, it was rated at 44 kv and consisted of a square sheet metal box with a wood lining. A contact arm rotated in a horizontal plane and was submerged in oil. It was actuated by a system of gearing and wood shafting which operated the three single-pole breakers for the circuit simultaneously.



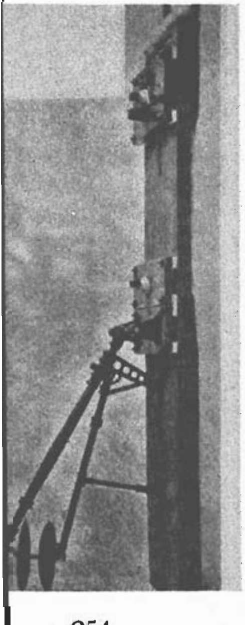
1902. 60 kv oil circuit breaker developed by R. H. Stirling for California transmission lines. It also was a horizontal break switch with separate tubs for each phase and operated through a rack mechanism, the handles for which can be seen at the top of the breaker.

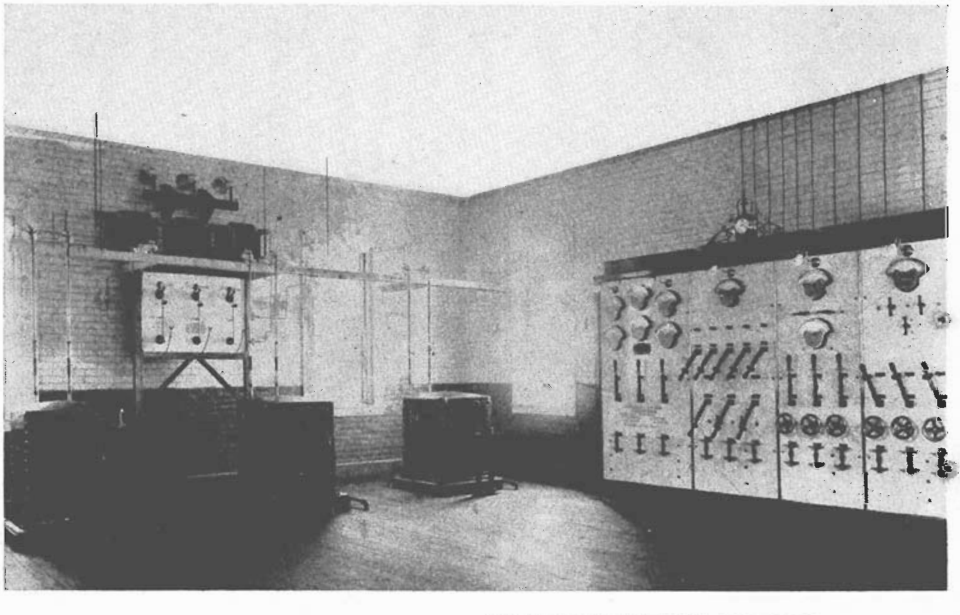
High voltage substation of the early 1900's on the PUBLIC SERVICE CO. OF COLORADO system. Open wiring and close spacing of conductors were hazardous, particularly in the case of a short circuit. The operator was afforded the protection of the sheet metal house. In the early days equipment was not available for outdoor designs.

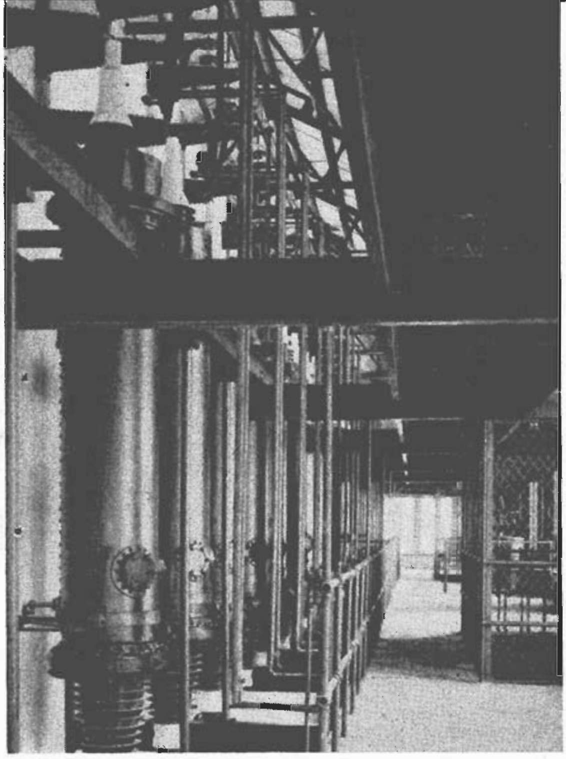


*Photograph courtesy of Wagner Electric Corp.*

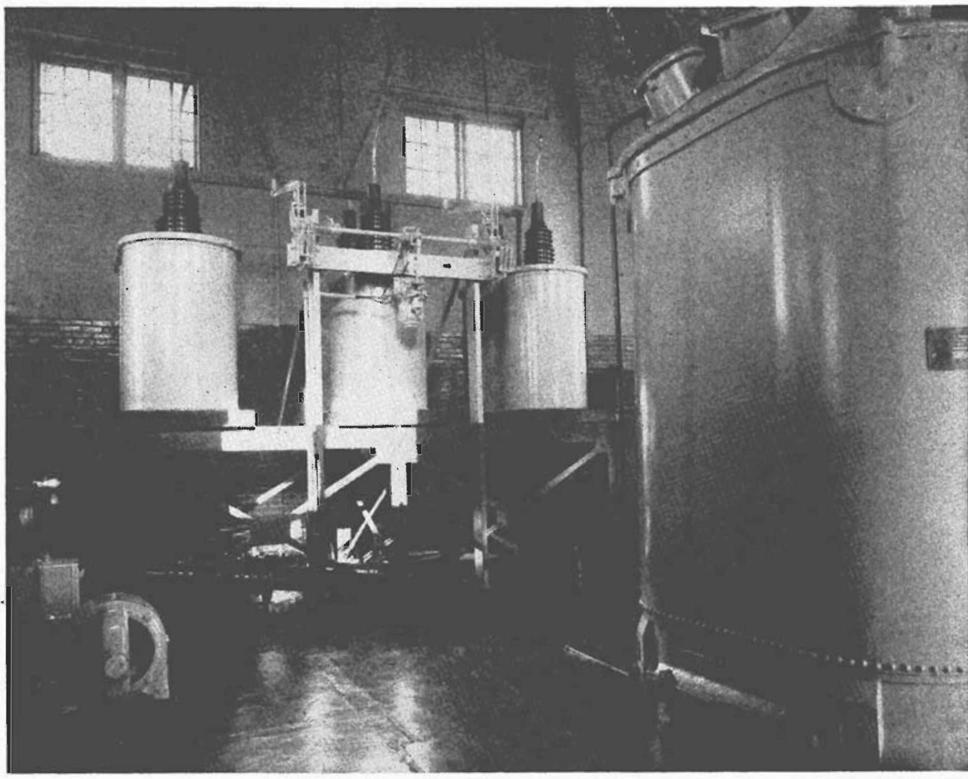
Below left is a view of the Stanley 40 kv, single pole combination fuse and switch, a very early attempt to combine circuit protection and interruption functions. Center — PACIFIC ELECTRIC's 60 kv circuit breaker of the 1906 vintage. This design consisted of oil immersed horizontal break contacts mounted in fiber tubs supported by porcelain insulators. In early designs, four breaks instead of two were adopted, giving better interrupting characteristics. Right — receiving end of early transmission line at Riverside, Calif., showing the transformers and switchboard design of about 1904. Note the three pole device above the transformers, which is apparently a form of fused disconnect.







**1908. General Electric's type "T" 100 kv breaker in use on PACIFIC GAS & ELECTRIC CO.'s system. It consisted of three vertically mounted metallic tubes with a stationary upper contact and a moving bayonet type contact, actuated by a pneumatic operator. Each pole was nearly eight feet high. One of the operating difficulties experienced involved oil leakage from the contact chamber which blocked air passages in the operator.**



**1910. This view of the type K-10, 100 kv breaker shows the rapid progress being made in switch gear design in the early 1900's. Note the arrangement of the operating mechanism and the general similarity to modern oil circuit breakers. The paper and fiber high voltage bushings were not suitable for outdoor operation.**

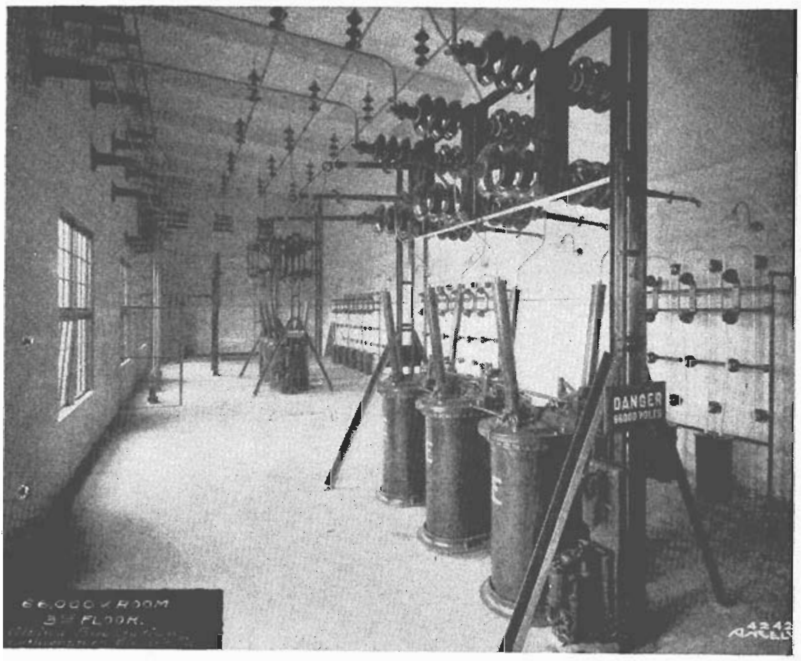
and apparatus has been made available at a lower cost and with a more definite knowledge of the protection obtained.

Early investigations of line interruptions due to flashovers disclosed that the majority were between one phase and ground. Further, the single-phase arcing ground apparently produced further breakdowns at other points on the high-voltage system. Two protective methods were developed. One was based on solid or low-reactance grounding on all or some power transformer neutrals; the other employed resonant neutral grounding through one or more ground fault neutralizers (see page 251). They function to suppress arcs caused by transitory ground faults and eliminate the service interruptions which would result from such faults on systems with the neutral solidly grounded.

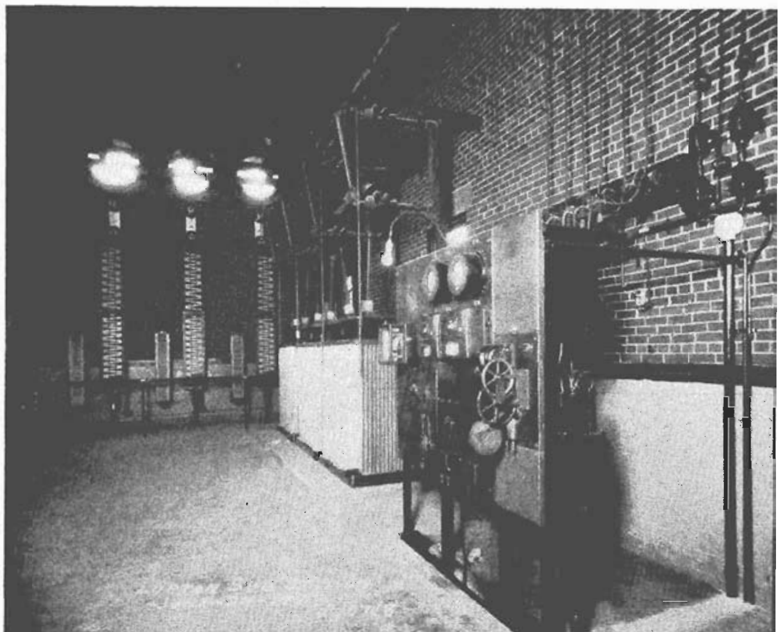
Analysis of a-c transmission problems was greatly aided by development of a-c network calculating boards upon which complete power systems could be set up in electrical miniature (see page 265). These studies resulted in producing economies in power and reactive flow, and in bringing about improvements and simplification in system operation.

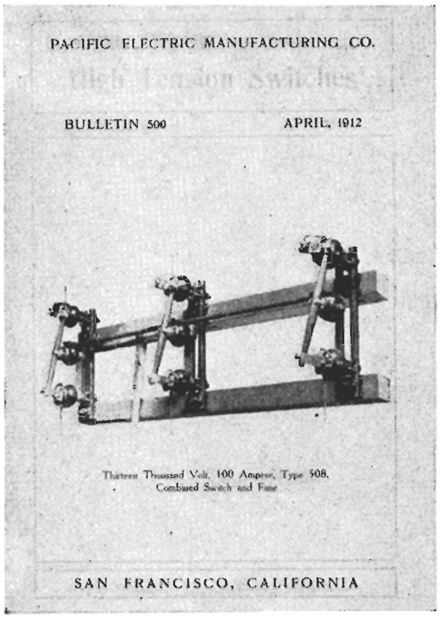
*(Continued on Page 257)*

**60 kv switchroom in a substation of the NORTHWESTERN ELECTRIC CO. illustrates design practices of 1912. Solenoid operated Westinghouse circuit breakers, shown in the center of the room, were equipped with fiber tube bushings. Note the open bus runs on the 60 kv circuit along the ceiling and walls.**



**This interior view of Lupton Substation of the PUBLIC SERVICE CO. OF COLORADO has several interesting features. In the background may be seen the early type multi-gap lightning arresters. In the center, note that the transformers use fiber bushings and are protected by the "grasshopper" fuse switch mounted above. In this switch the contact arm was held in the closed position by means of a fuse wire. When trouble occurred the fuse link melted and the arm dropped in a vertical arc drawing the arc out and sometimes hitting a station operator who might be standing directly underneath. On the switchboard there appears to be an early form of reclosing mechanism for an oil circuit breaker.**





PACIFIC ELECTRIC MANUFACTURING CO.

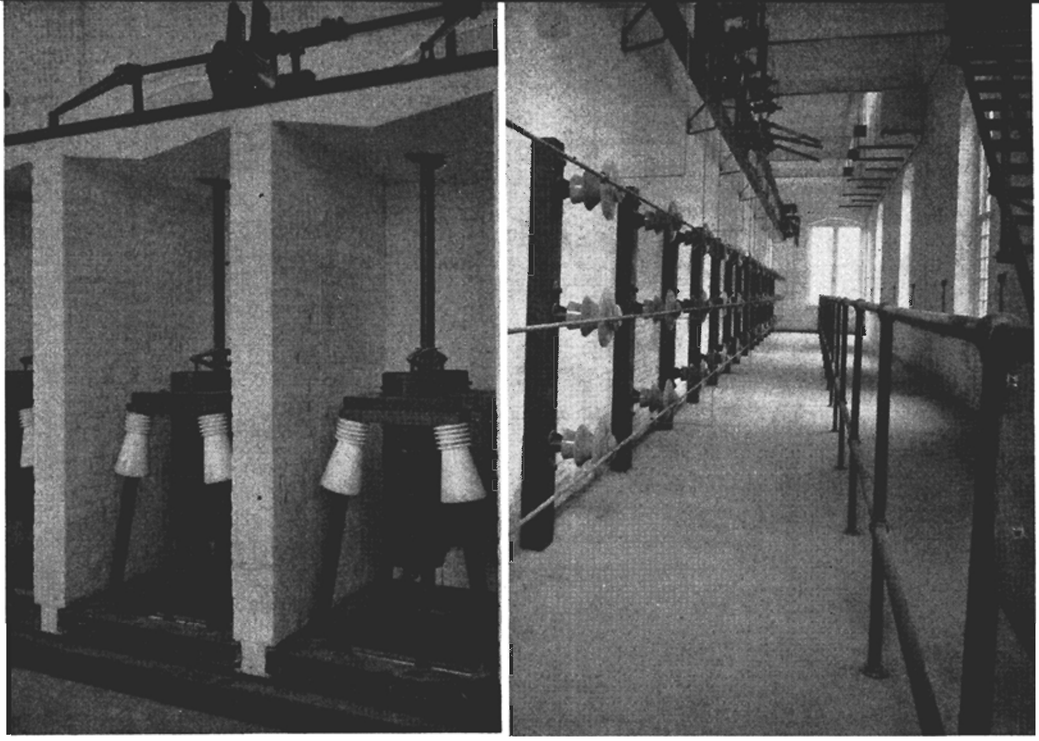
High Tension Switches

BULLETIN 500 APRIL, 1912

Thirteen Thousand Volt, 100 Ampere, Type 508,
Combined Switch and Fuse

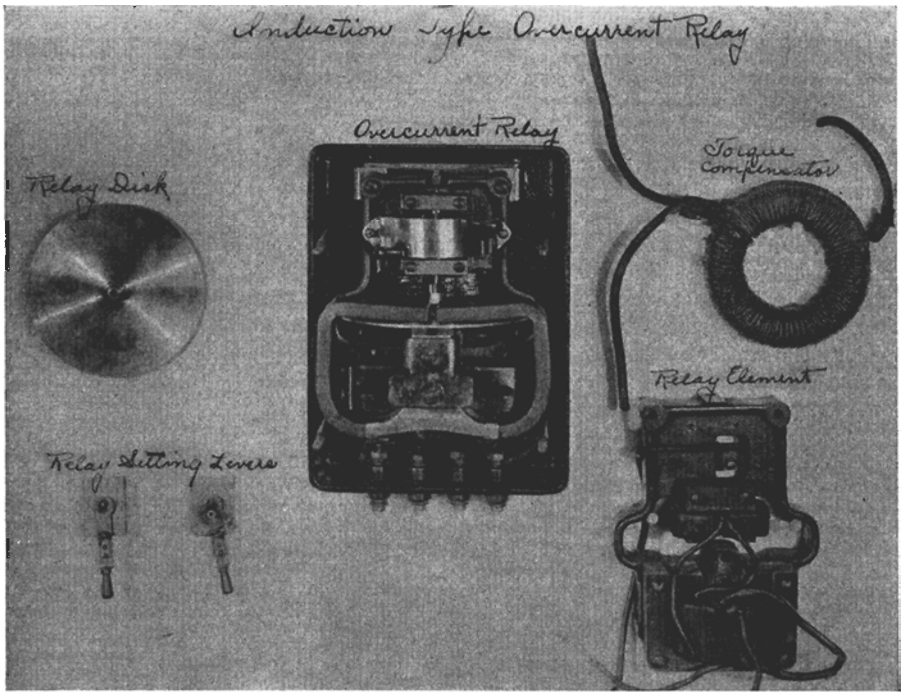
SAN FRANCISCO, CALIFORNIA

**Cover reproduction of a 1912 bulletin of the Pacific Electric Manufacturing Co., showing the gang operated 13 kv, 100 ampere, combined fuse and switch offered at the time. The fuse link on the operating arm was threaded through the wooden holders pivoted on the center insulator.**

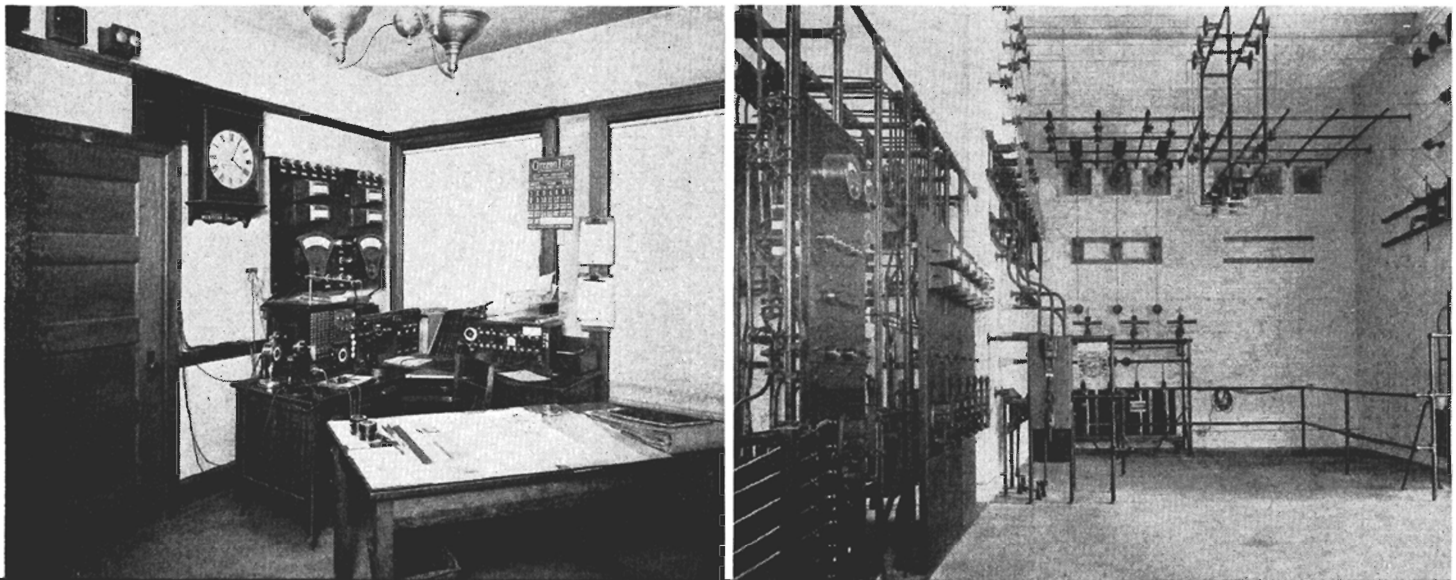


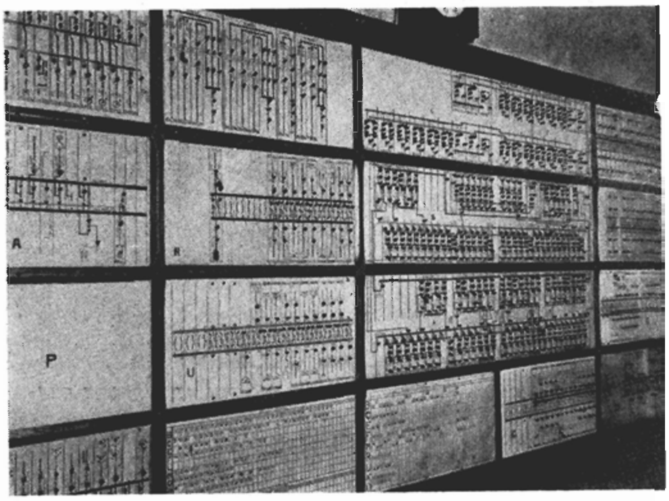
**Above left — 60 kv General Electric oil circuit breaker used in the early 1900's. Phase contacts were carried in separate wooden tubes supported on wood legs capped with porcelain insulators. These breakers were installed by the WASHINGTON WATER POWER CO. Above right — 60 kv bus room of the same era.**

**Induction type overload relays were introduced in 1902 and provided the first major improvement in circuit protection against fault currents. A further improvement, developed by engineers of the CONSOLIDATED GAS, ELECTRIC LIGHT AND POWER CO. of Baltimore added a torque compensator which changed the operating time of the induction relay from variable inverse time to inverse definite time characteristics, making better coordination of circuit protection possible. The torque compensator was first used in 1911 and the design was subsequently adopted by electrical manufacturers for over-current relays.**

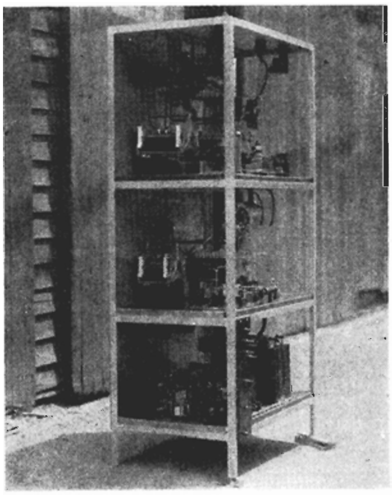


**Below left — In 1913 the load dispatcher's office on the PORTLAND GENERAL ELECTRIC CO.'s system looked like this. Load dispatching became increasingly more important as systems grew in size and complexity. Below right — substation design in 1916 as developed on the BROCKTON EDISON CO. system. High voltage circuits are given more clearance and are located so as to be relatively inaccessible to accidental contact.**



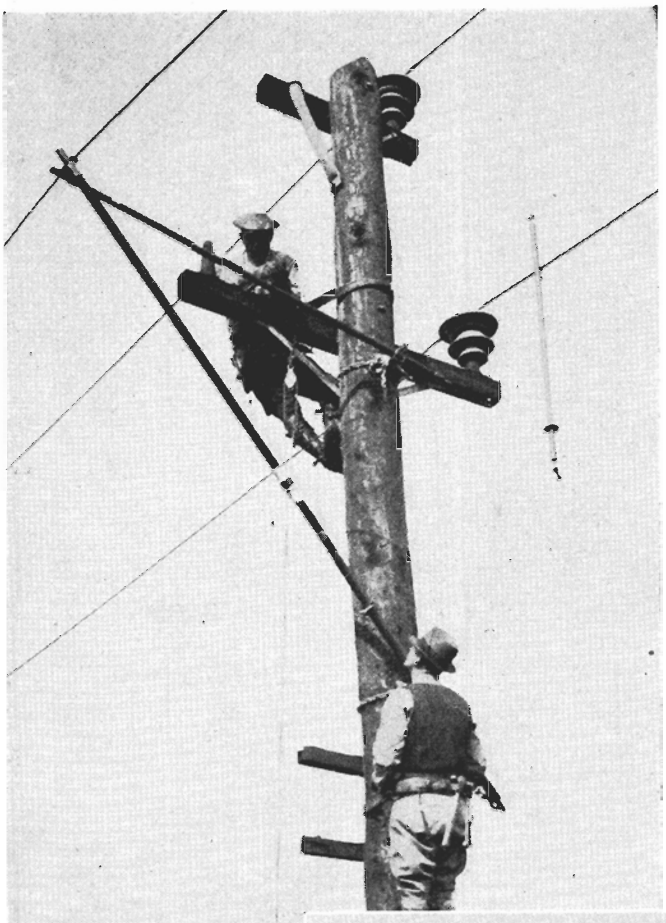


The growing complexity of power systems during World War I years is illustrated by this view of the system dispatcher's board of the **CLEVELAND ELECTRIC ILLUMINATING CO.**

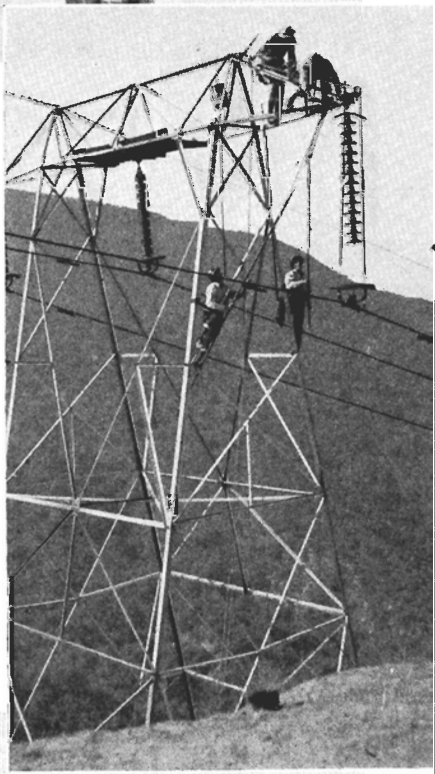


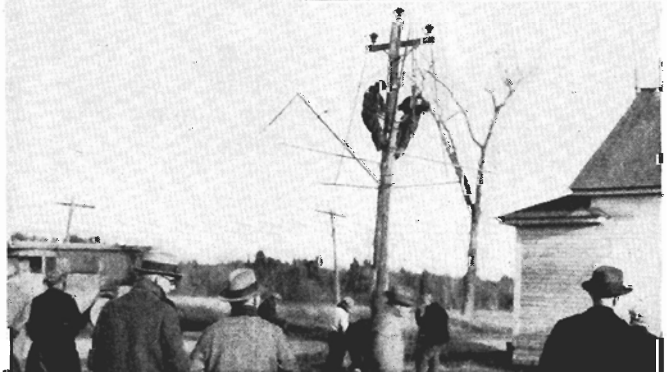
The need for reliable intra-system communication fostered the use of spark radio installations in the early 1920's? Even though slow and relatively crude, radio could be operated when other communication facilities were out. Views at the left and below show the transmitter and aerial employed by the **PENNSYLVANIA POWER & LIGHT CO.** in 1922. Other companies which pioneered radio communication included the **NORTHWESTERN ELECTRIC CO.**, the **GEORGIA POWER CO.**, and the **MONTANA POWER CO.** Modern practice employs frequency modulated two-way voice communication.

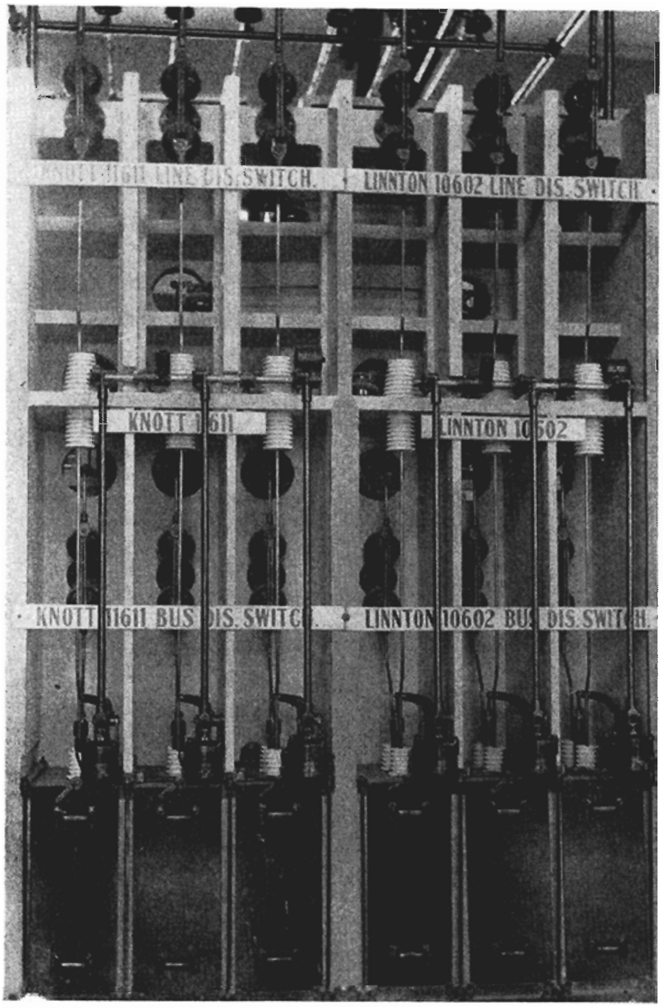
In addition to control of lightning surges, there were the still broader investigations necessary to protect service and equipment from all types of faults which might occur, to provide means of controlling power flow over the increasingly complex transmission grid which was being developed, and to establish methods of isolating portions of the system which developed trouble rapidly and efficiently so as to reduce service interruptions to a minimum.



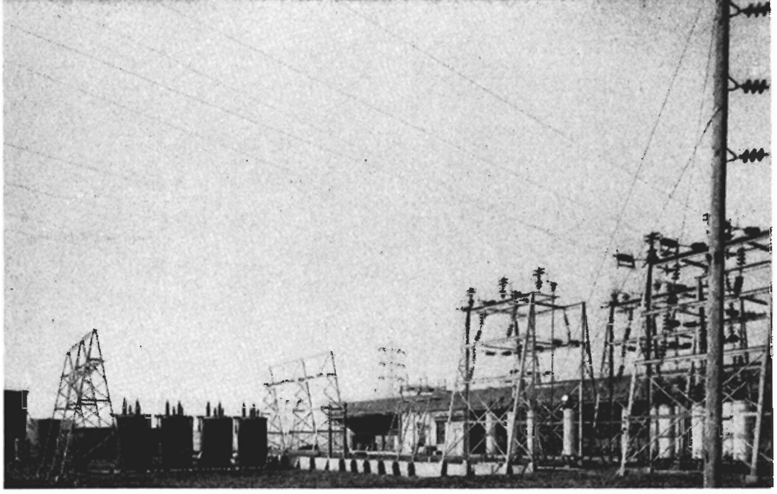
As the uses of power became more diversified in the 1910-1920 period, power companies found it increasingly detrimental to interrupt service in order to repair or maintain transmission lines. The alternative was the development of procedures whereby high voltage lines could be worked on while energized, with safety to the line crews. The **GEORGIA POWER CO.** pioneered in this development when, in 1913, one of its employees developed the first hot line clamp. The rapid development in the art of working lines "hot" is indicated by the photograph below taken on the system of the **BANGOR HYDRO ELECTRIC CO.** in 1926. It is modern practice to work even the highest voltage lines while they are energized, the view at the right showing a line crew changing an insulator string on a 220-kv circuit.






KNOTT 11611 LINE DIS. SWITCH
LINNTON 10602 LINE DIS. SWITCH
KNOTT 11611
LINNTON 10602
KNOTT 11611 BUS DIS. SWITCH
LINNTON 10602 BUS DIS. SWITCH

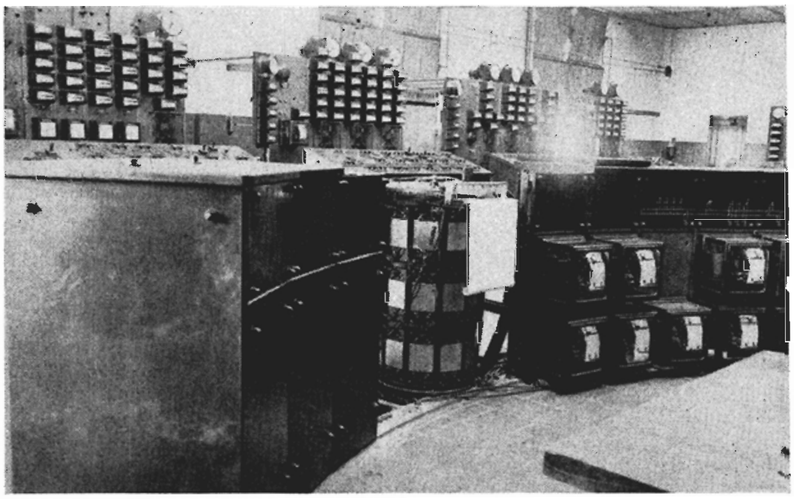
**The isolation of each phase of a high voltage circuit by the use of cells and barriers became popular in the second decade of the 20th century. This view shows the counterweighted operating mechanism on early oil circuit breakers and the porcelain bushings used to carry phase conductors through the cell structure.**



**1915. This high voltage substation on the CAROLINA POWER & LIGHT CO.'s system is of the era when high voltage equipment was being moved out of doors. Note the use of wedge-shaped steel supporting structures and the use of conductor for overhead buses. Also, the disconnect switch included as an integral part of the dead-end insulator string at the extreme right.**

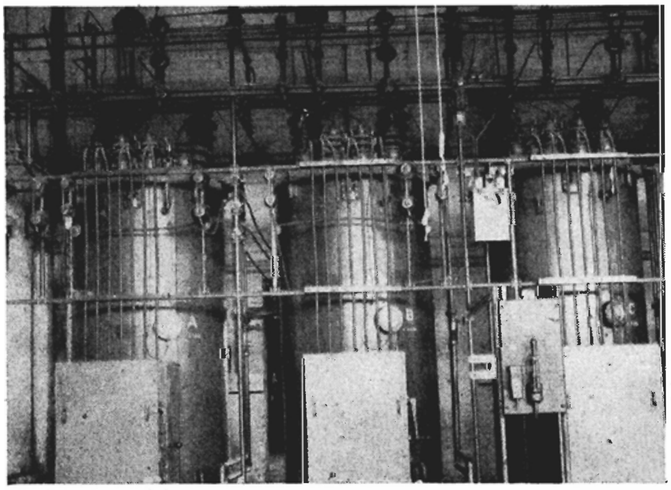
**1917. As plants grew, it became desirable to measure the total output from a number of different units. This totalizing wattmeter installed in the Keokuk Station of the UNION ELECTRIC CO. of St. Louis had 24 separate integrating elements mounted in three radial tiers of eight each. Present day practice requires a centralized record of the output of widely scattered power plants and the transmitting of the power flow indications from distant tie-line points. A common way of accomplishing this today is by carrier current impulses.**

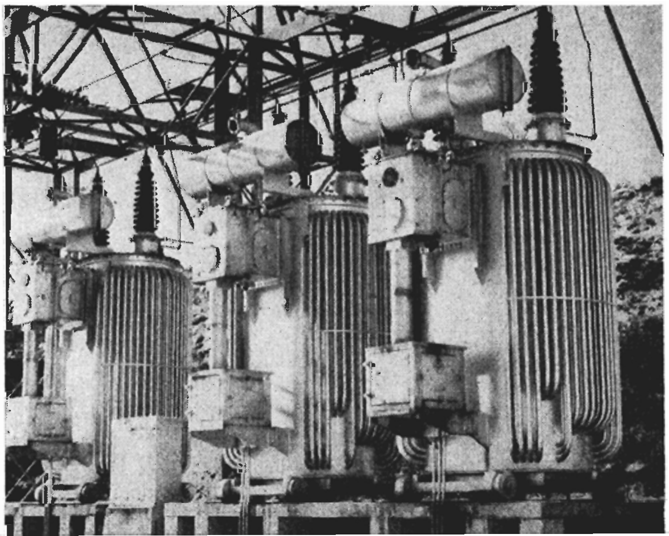
*Photo courtesy of the Esterline-Angus Co.*

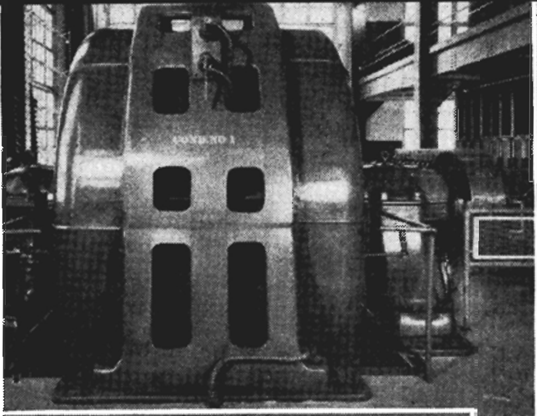


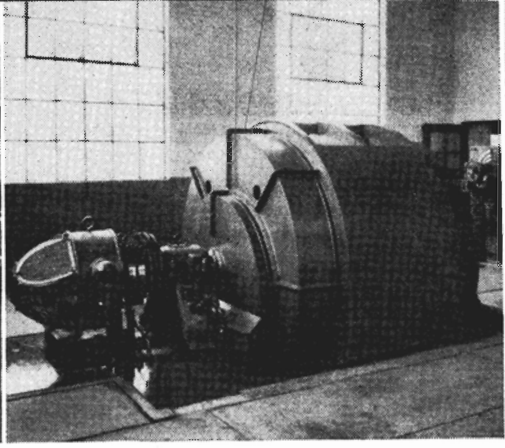
Development of more complicated transmission networks made tap-changing-under-load equipment for power transformers more and more essential. This development functions to control the secondary voltage, the flow of reactive kva between two generating systems or between branches of loop circuits, or to control the division of power between branches of loop circuits by shifting the phase-angle position of transformer output voltages. One of the pioneer installations of tap-changing-under-load equipment was made on a 132-kv interconnection

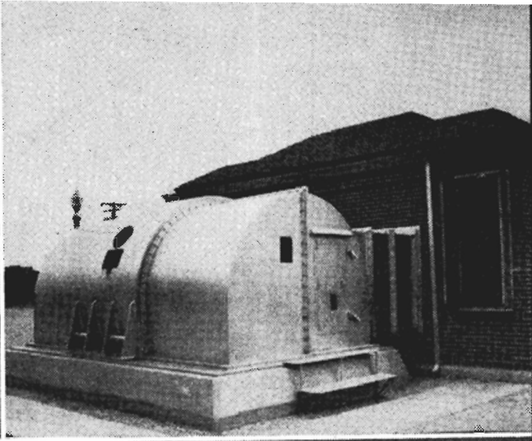
**One method of providing the customer with uniform voltage conditions is the use of tap changing devices on transformer banks which vary the ratio of transformation. Below left is an early, manually operated tap changing regulator connected into the ground end of the 12-kv winding of this 60/12 kv transformer bank. It was used by the PACIFIC GAS & ELECTRIC CO. in the early 1920's. Below right is a more modern installation installed on the BANGOR HYDRO ELECTRIC CO's system in 1930. The tap changing mechanism is built as an integral part of the transformer and operates automatically to compensate for supply voltage changes.**

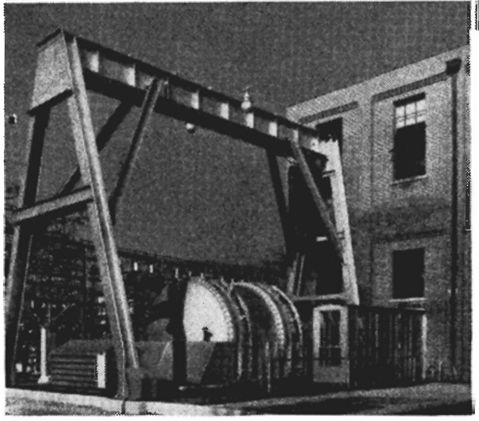


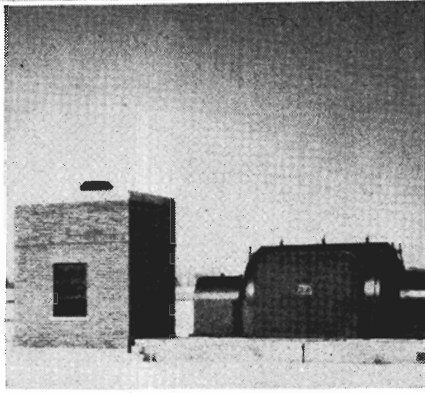










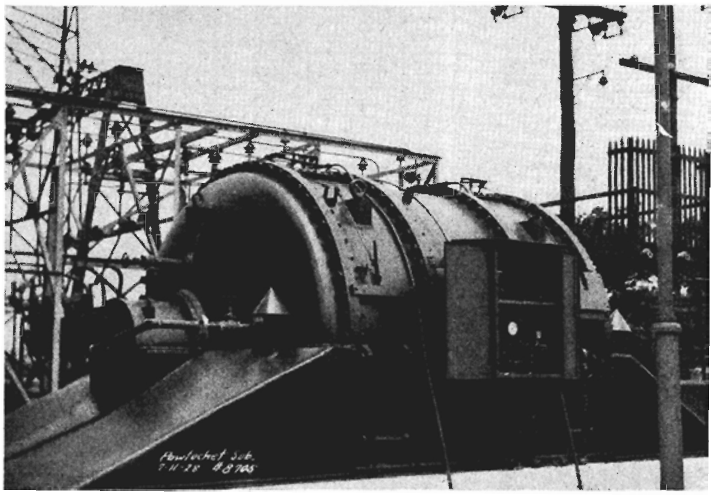


**Synchronous condensers were early recognized as a desirable method of transmission line regulation. The accompanying photographs, of installations on the AMERICAN GAS & ELECTRIC CO.'s system, show the evolution of synchronous condenser design. Left above — a 7,500 kva, 400 rpm condenser installed at Canton, Ohio, in 1916. Above center — a 1925 installation at Ashland, Ky., rated at 7,500 kva, 900 rpm, showed that higher speeds made a more compact installation. Above right — in 1929 a major step was taken to reduce investment costs of the building by adapting an indoor machine for outdoor operation. This unit was rated at 15,000 kva, 900 rpm. The installation shown directly to the left illustrates a second revolutionary step, that of operating an outdoor synchronous condenser in hydrogen, which increased its kva rating by about 25 per cent. The installation at the right represents still greater economy through higher speed, this being a modern outdoor hydrogen-cooled, 3,600 rpm unit, rated at 30,000 kva. It is essentially the same physical size as the 15,000 kva shown directly above.**

between the systems of the Consumers Power Co. and the Detroit Edison Co. in 1928.

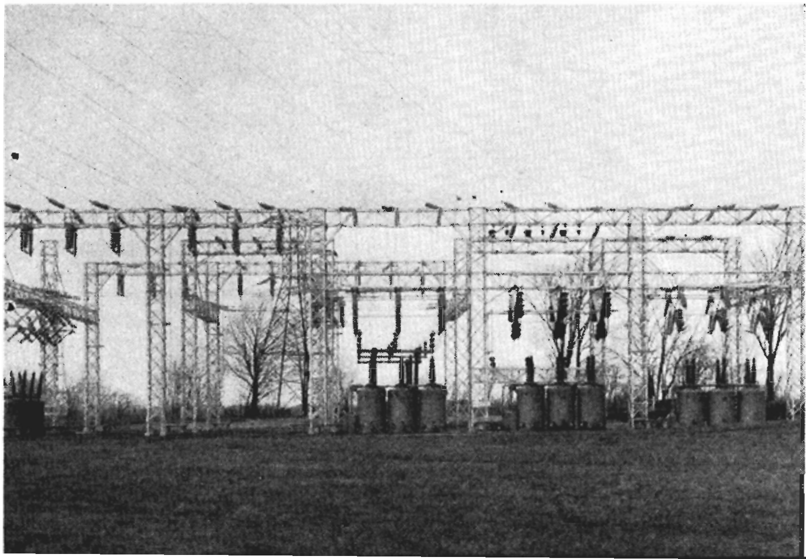
The phase-shifter, or quadrature voltage regulator, is a device developed to control power flow in transmission networks. Its possibilities were recognized early by the Duquesne Light Co., which made extensive tests in 1928 on an interconnected loop about 250 miles in length and directly involving five power companies. In 1937, this company followed up this early investigation by installing a 20,000-kva 66-kv 28-degree phase shifter. Many other regulators of this type have been installed by power companies.

Communication between widely scattered stations on power systems became of increasing importance with system growth. Although commercial telephone service sufficed for a number of years, there arose a general need for supplementary types of communication equipment. Considerable work was done in the development of space radio communication in connection with early power system operation. In the early 1920's the use of

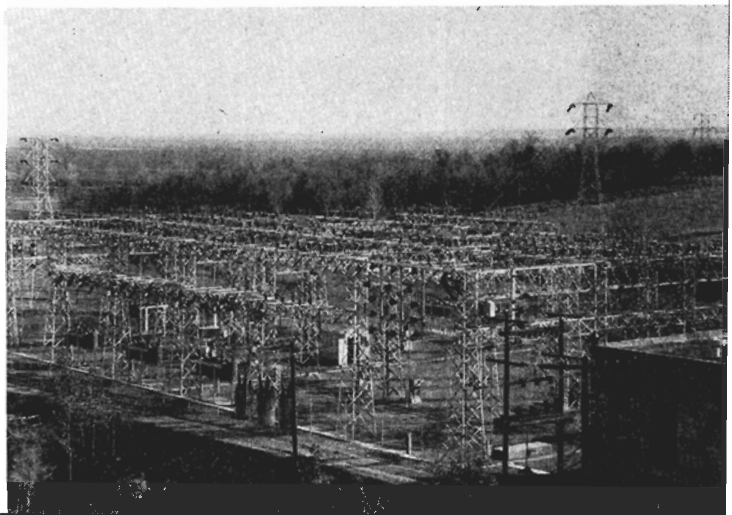


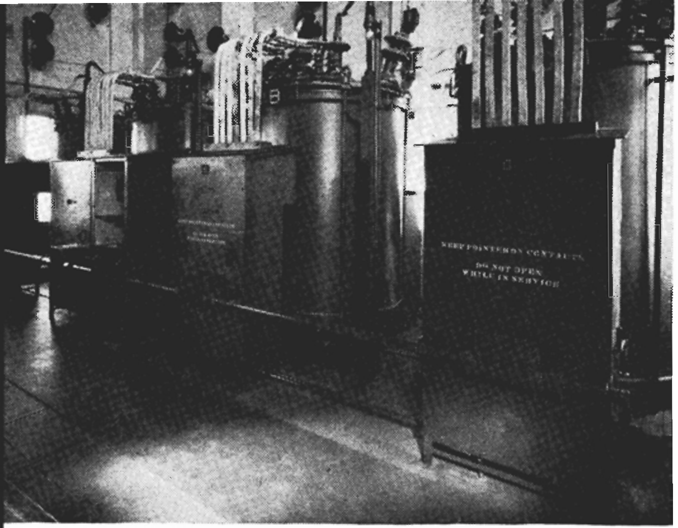
**1928. The first hydrogen-cooled synchronous condenser was placed in operation on the NEW ENGLAND POWER CO.'s system at Pawtucket, R. I. This pioneer installation marked the beginning of the trend to operate both condensers and a-c generators in hydrogen for greater economy. Hydrogen cooling makes possible greater electrical output from a given physical size, cuts costs and losses.**

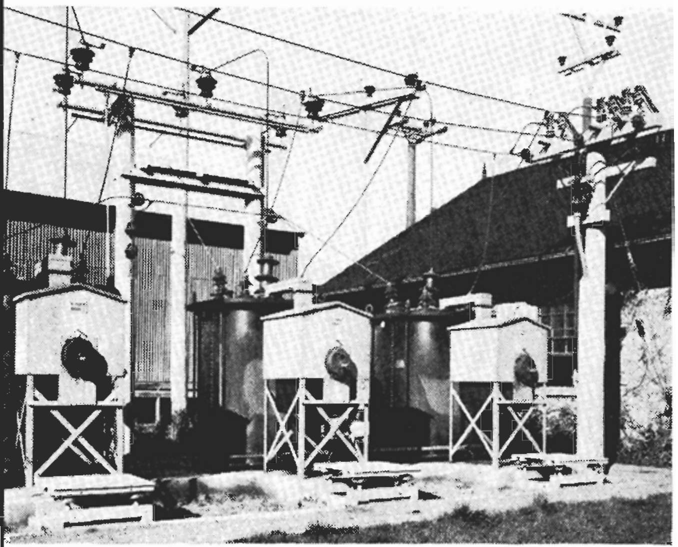
**1923. System growth led early to standardization of equipment and structures. Since the early '20's, the NIAGARA-HUDSON POWER CORP.'s system in central and western New York has used standard steel structures for all 115-kv circuits. This has reduced costs of design and allows structural steel units, retired due to changes, to be re-used elsewhere on the system.**

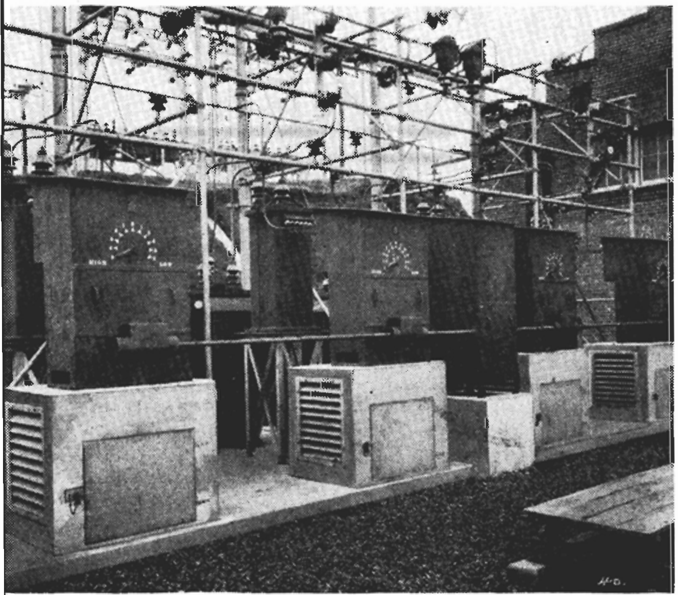


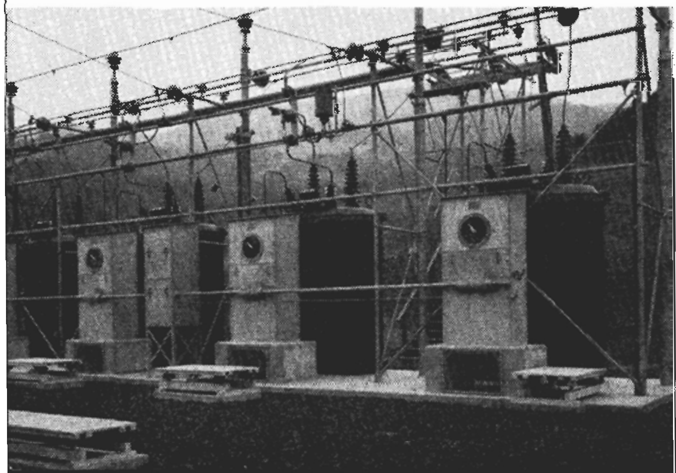
**Substation on the TEXAS POWER & LIGHT CO.'s system indicates the growing concentrations of power that were being developed in the middle 1920's. This station operated with 138-kv high voltage bus and is typical of the larger substation construction of the era.**











**The four views shown at the left indicate the development of "tap changing under load" on the PACIFIC GAS & ELECTRIC CO.'s system. At the top may be seen an early form of automatic tap changing mechanism for an indoor installation. Immediately below is a hand-operated outdoor type of tap changer. The third picture from the top shows a still later modification which provided automatic operation through the use of the actuating mechanism shown at the center. Note that the tap changing winding is mounted separately from the main transformer, directly in the rear of the regulating head. At the bottom is a still later design with the regulating winding included as an integral part of the transformer. In the two lower installations, the contacts are shorted through globar resisters during the movement of the regulating arm.**

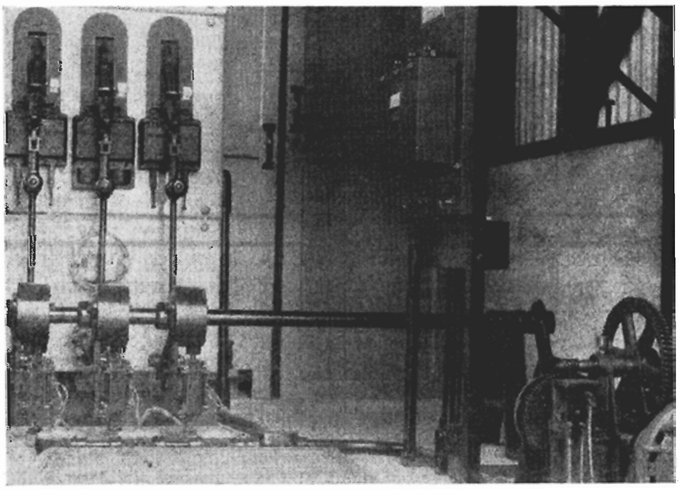
carrier frequencies superimposed on the transmission lines was investigated. This has resulted in providing direct and dependable channels now used for both communication and relaying.

One of the first carrier current communication systems was installed by the Lake Superior District Power Co. in 1921, on an 87-mile 88-kv transmission line.

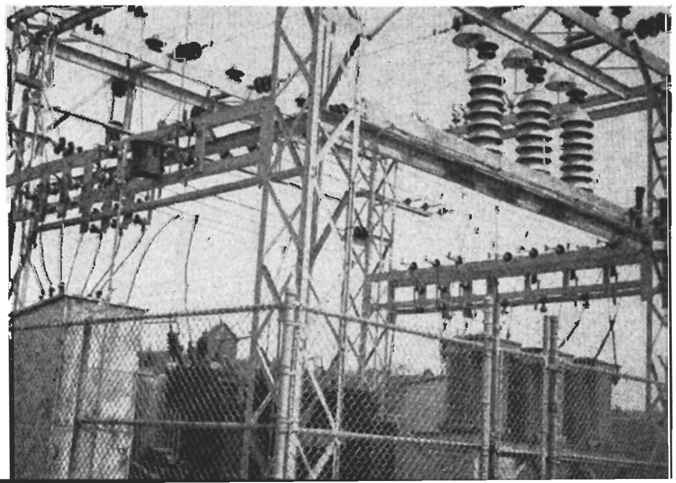
### Relay Applications

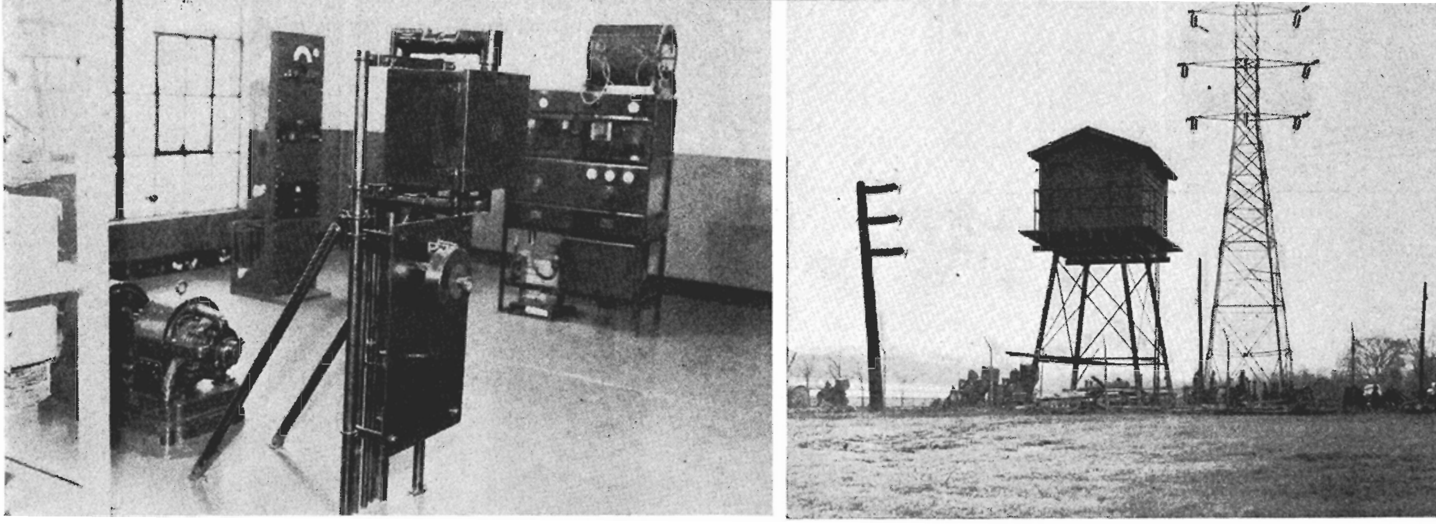
The principal function of relays and circuit breakers in the operation of a pioneer system is to prevent or eliminate damage during line flashovers or other disturbances, and to minimize their effect on the remainder of the system. The time required for these devices to perform this function is a direct measure of their effectiveness. Through the introduction of carrier current and pilot wire relaying equipment, the time required for relay operation has been reduced to approximately one cycle, in terms of a 60 cycle system. At the same time, high-speed circuit breakers have been developed with a total tripping time of from three to five cycles. The achievement of total clearing

*(Continued on Page 262)*

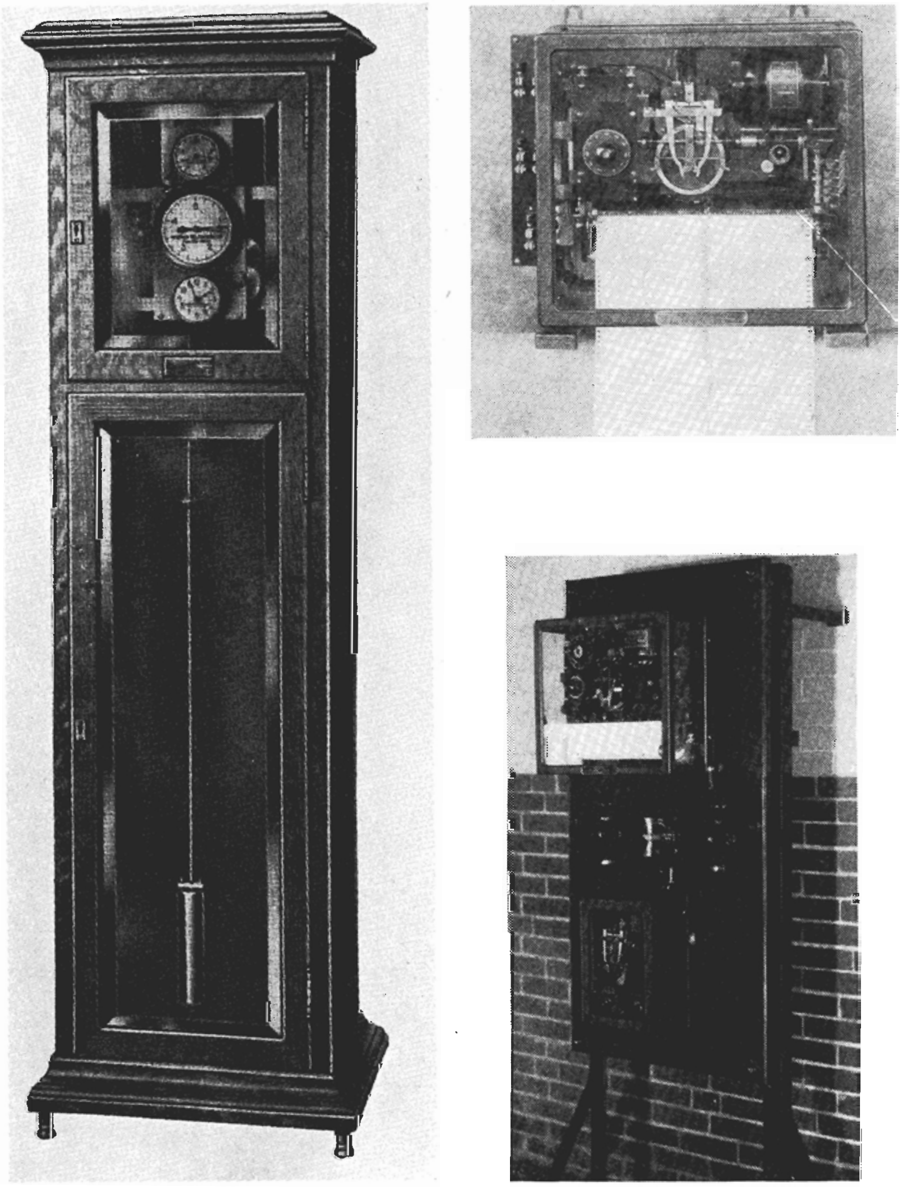


**Automatic reclosing of circuit breakers after tripping often saves a lengthy service outage, as the initial fault may clear itself while the line is de-energized. Above is an early form of improvised reclosing mechanism adapted to an old type of manually operated circuit breaker. Below is the first automatic reclosing breaker, in use on the BANGOR HYDRO ELECTRIC CO.'s system, in 1924. The relays, actuator, and breaker itself are enclosed in the housing shown at the left.**

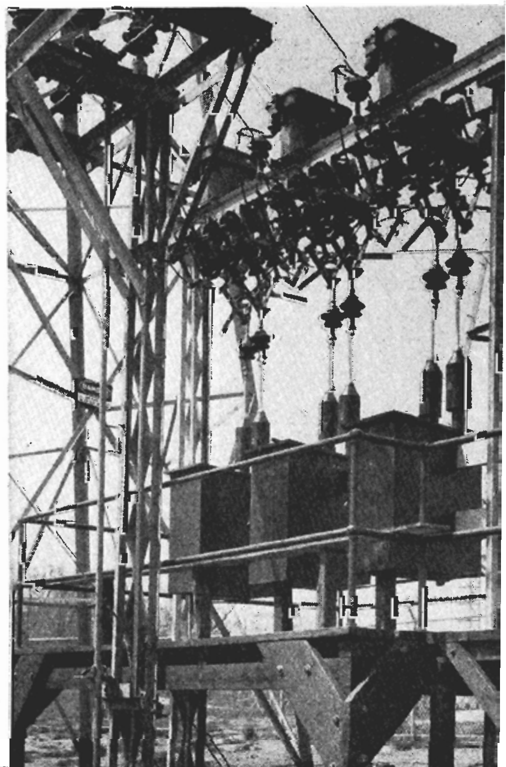




**One of the first permanent carrier current telephone installations was placed in service by the OHIO EDISON CO. between this company's Toronto generating station and the load dispatcher's office in Youngstown, via the Boardman Substation. Shown above (left) is the Toronto equipment, and above (right) the antenna house at the Boardman Substation. Aerial coupling wires extended for a distance of three span lengths from each end of the double-circuit 138-kv line. Despite some difficulty with this pioneer equipment, the installation is considered to have been justified by virtue of its availability during severe storm periods when other forms of communication were out of service. The OHIO PUBLIC SERVICE CO. also pioneered carrier equipment.**

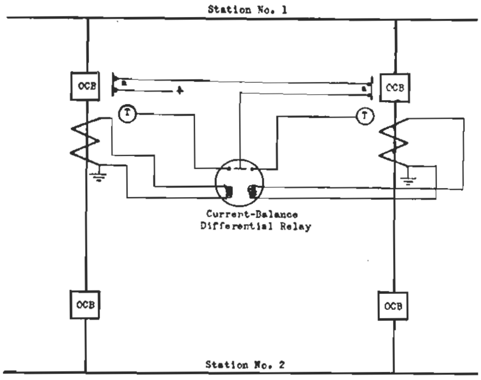


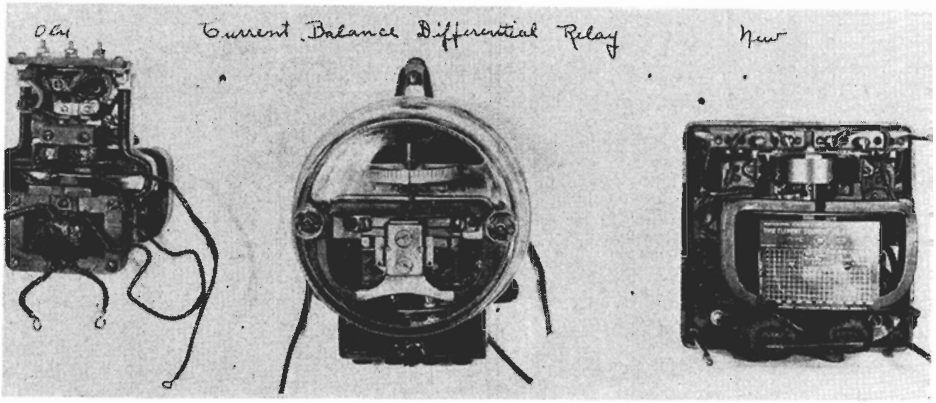
**Milestones in the automatic frequency regulation of power systems are shown in these views. 1917—(at the extreme left) is a master synchronous clock installed by the CONSOLIDATED EDISON CO. OF NEW YORK, INC. which showed on a common dial the deviation of system frequency from clock time. 1925—(above left) the first impedance bridge-type frequency recorder was installed in the load dispatcher's office of the PHILADELPHIA ELECTRIC CO. In 1927 the first proportional-step, automatic frequency controller was installed on the NEW ENGLAND POWER CO. system and relieved operators of manually regulating frequency from observation of graphic instruments. The latter also pioneered, in 1934, tie-line bias control equipment (lower left) which is now the accepted type of automatic system regulation on all major inter-connected power systems.**



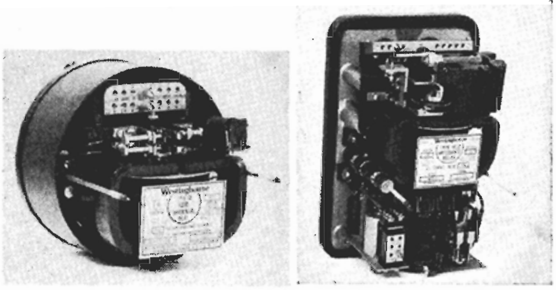
**Development of reclosing-type fuses, permitting immediate restoration of service on most lines subjected to transient disturbances, effected a major improvement in customer service. One of the first automatic fuse renewing devices was developed for 13-kv overhead feeders by engineers of the CONSOLIDATED GAS, ELECTRIC LIGHT AND POWER CO. OF BALTIMORE in 1927. This device, shown at the right, consisted of a spring-closing disconnect, a breaker hand closing lever equipped with a potential trip coil, and a potential transformer. The disconnect was mounted in series with a spare fuse and held in the "open" position by the hand-operated lever. A fuse blowing energized the potential transformer through the spare fuse in series with the line load, tripping the release mechanism and permitting the disconnect to close and put the spare fuse in service.**

Schematic Connections of Current-Balance Differential Relay





**1919 — To select and clear a faulted circuit operating in parallel with other circuits, an engineer of the CONSOLIDATED GAS, ELECTRIC LIGHT AND POWER CO. OF BALTIMORE developed the current-balance differential relay shown on the left in the photograph above. On the right, in the same photograph, is the relay as built at a later date by the Westinghouse Electric Corp. The sketch at the left shows schematically the connection of this relay. Prior to this time, circuits other than the faulted one were often tripped, resulting in a needless interruption to service.**



**In 1925, an engineer of the PUBLIC SERVICE ELECTRIC AND GAS CO. developed the design for the ratio differential relay (left). Since that time, the majority of the differential protection equipment on systems throughout the country utilizes the percentage differential principle involved in this relay. The impedance relay (right), designed for transmission line protection, was also a development of an engineer of this same company, in 1932. These two developments represented a major forward step in protection of power system equipment and the betterment of service.**

times of this order has substantially eliminated damage to transmission conductors and insulators as a result of flashover, and has greatly relieved the stress on the system as a whole. Reduction of the duration of surges on the system has increased the reliability and quality of transmission service. In addition, the use of ultra-rapid reclosure has lessened the need for double circuit lines primarily employed to maintain a high degree of service continuity.

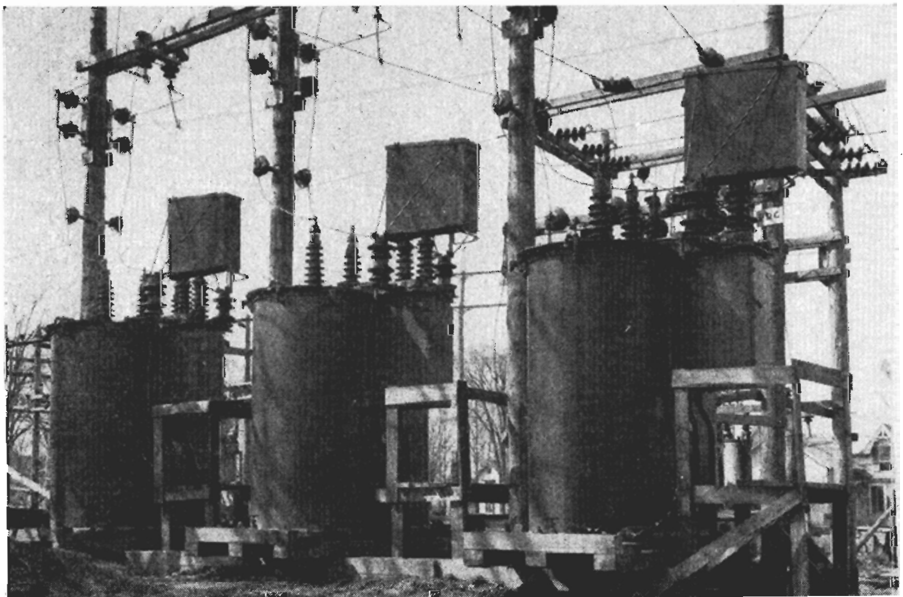
Another approach to the problem of high-speed clearing of transmission line flashovers was the development of "isolated phase" protection. With this system, single-pole reclosing breakers are used which operate individually to clear single-phase faults. This type of switching also required the development of an entirely new protective relay system.

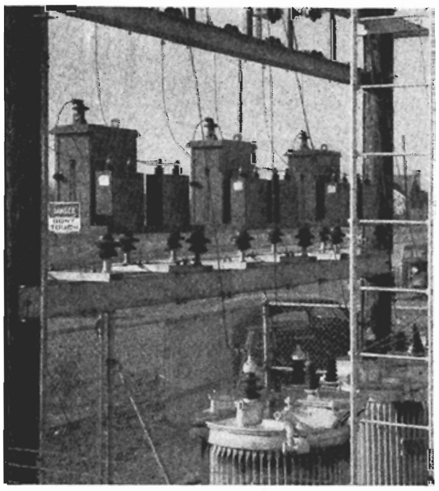
Theoretically, a grounded neutral 3-phase transmission network can carry 57 per cent of its line capacity successfully and maintain stability with one wire interrupted. Thus, the single-pole switching scheme, by isolating the one wire in trouble on a high-voltage transmission network, would result in a system capable of maintaining stable operation over a longer period of time and, therefore, could employ standard breaker equipment, in contrast to the special breaker equipment required for the three-pole ultra-rapid reclosing scheme (see page 266).

## RELAY DESIGN

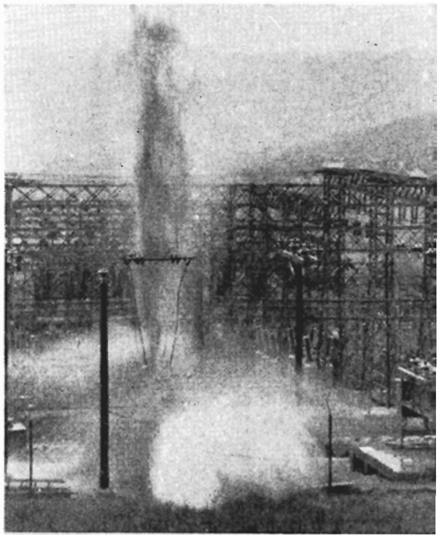
Protective relay designs have undergone radical changes to meet the increasingly severe relaying requirements. System protection started with the induction-type overload and reverse-power relays. The directional over-current relay was introduced

**1928 — Pioneer installation of high voltage series capacitors, installed on the NEW YORK POWER AND LIGHT CORP. system. The capacitor was rated at 1245 kva and was part of a 33-kv circuit which was normally paralled with 66-kv circuits. Installation of this series capacitor improved load division between the 33-kv and 66-kv circuits and permitted transmission of power without excessively high sending-end voltage.**





**1938 — OKLAHOMA GAS AND ELECTRIC CO. pioneered in the cooperative development of simplified, lower cost protective equipment for series capacitor installations, a typical one of which is shown here. Prior designs were complex and costly.**

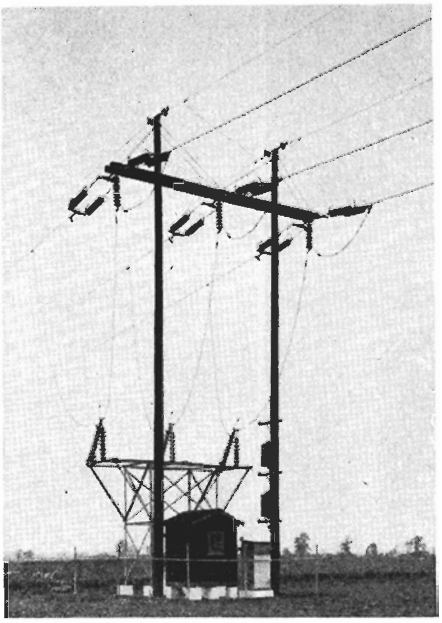


**1923 — THE DUQUESNE LIGHT CO. early realized the need for field testing facilities to determine performance of large breakers. This company maintained a field testing station for a period of six years, until the manufacturers could equip their laboratories with testing facilities of sufficient capacity. This view indicates the spectacular nature of some tests. Resultant design improvements benefited all users.**

◀

▶

**1925 — Early development work on carrier current telephony and supervisory control over power lines was conducted by the ALABAMA POWER CO. The company realized that its power service could be no better than its communication system, and also that quick isolation of trouble on long transmission lines would materially improve service. This is a supervisory-controlled 110-kv sectionalizing switch on a single-circuit line over which it was found possible to signal and talk with a fair degree of reliability, thus demonstrating the practicability of such equipment.**



in 1910. The definite minimum-time characteristic, which was added in 1914, simplified the relay application problem. Introduction of the distance-measuring relay in 1922 was followed by the development of the high-speed impedance relay in 1929, providing one-cycle operation.

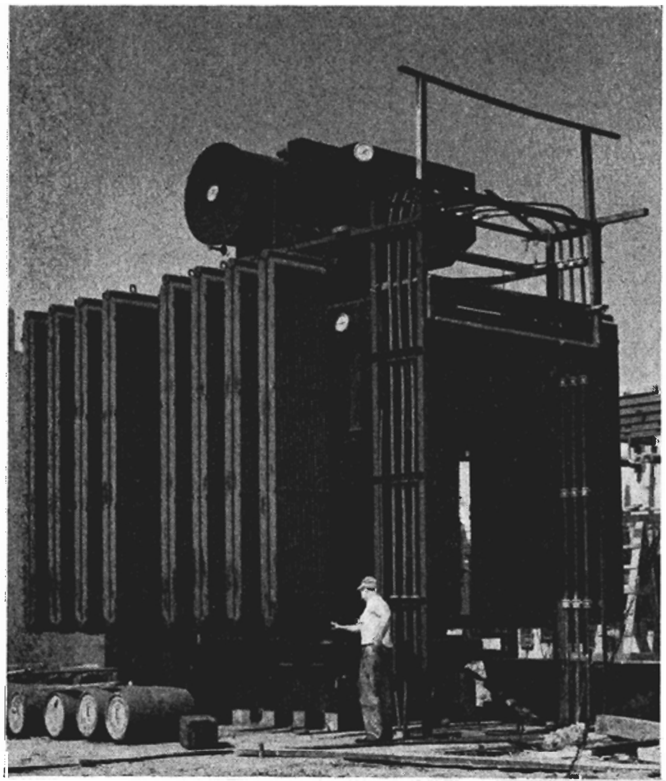
By 1935, carrier current relaying had become practical, making available uniform high-speed action throughout the entire line section. A short time later, in 1938, introduction of the pilot wire relay, based on symmetrical components, made one-cycle operation practical over a-c pilot wires.

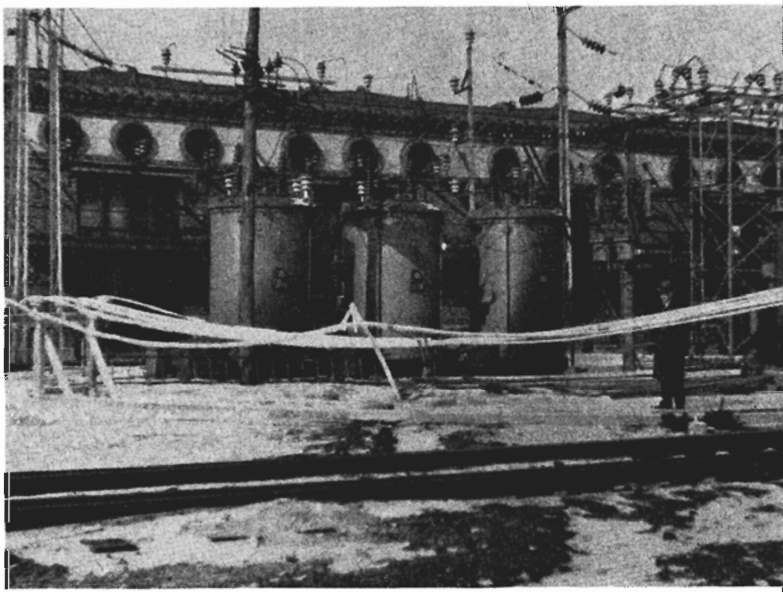
### Series Capacitors

An economic and effective means of improving further the performance of power systems was provided with the development of the series capacitor. This equipment provides a boost in voltage to compensate for sudden dips due to heavy starting currents required by large industrial plant motors, or similar

*(Continued on Page 266)*

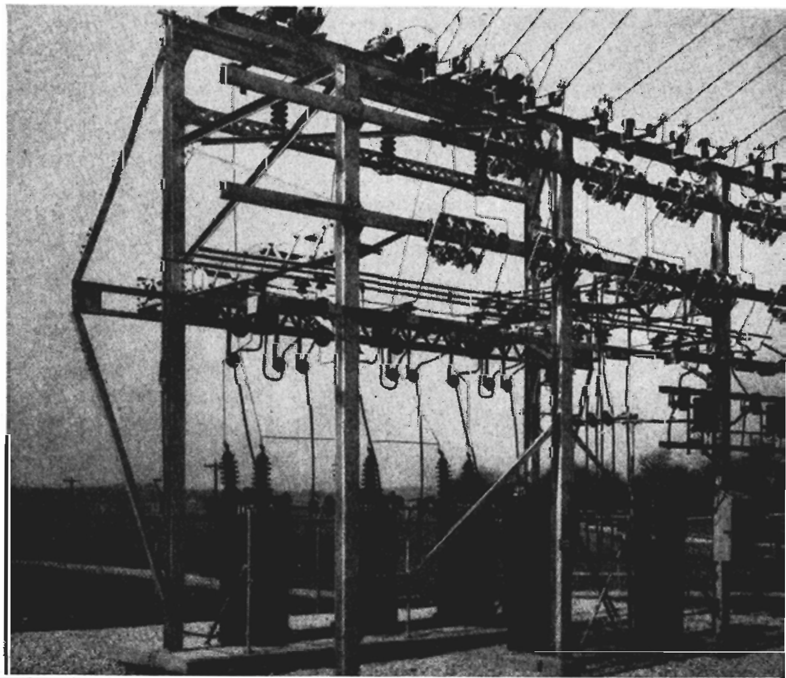
**Development of phase-angle regulating transformers placed an essential tool in the hands of power system engineers for control of power flow on important interconnections. This 12,500 kva, 88-ton unit in service on the NEW ENGLAND POWER CO.'s system was shipped complete with core and coils in place and filled with oil.**

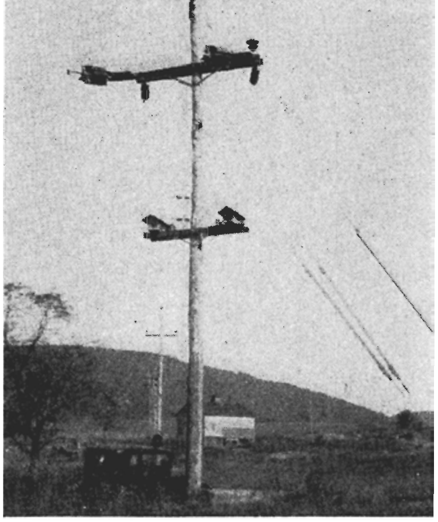




**1928 — Illustrative of utility efforts to improve service by conducting field tests on lines and equipment is this view of the BUFFALO NIAGARA ELECTRIC CORP.'s sleet melting investigations, in which high current was circulated through transmission line conductors, a practice now commonly followed to prevent line failure from ice loading.**

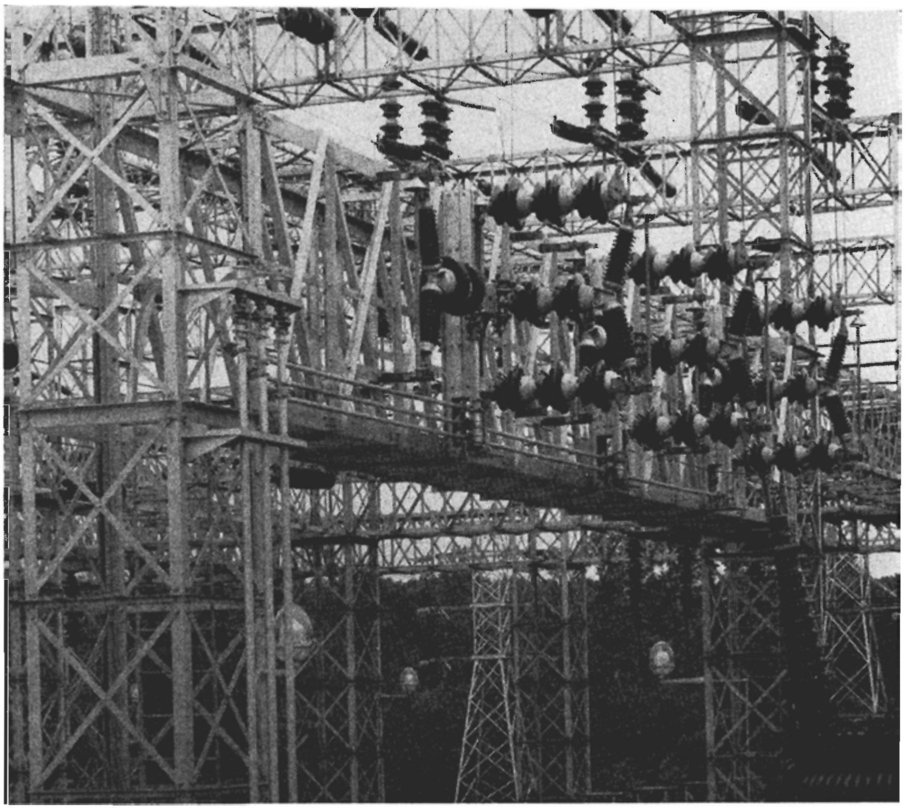
**1929. Reclosing fuses provided engineers with a compromise between protection for equipment and improved continuity of service. Below is a WISCONSIN ELECTRIC POWER CO. substation showing installation of nine three-shot reclosing fuses.**

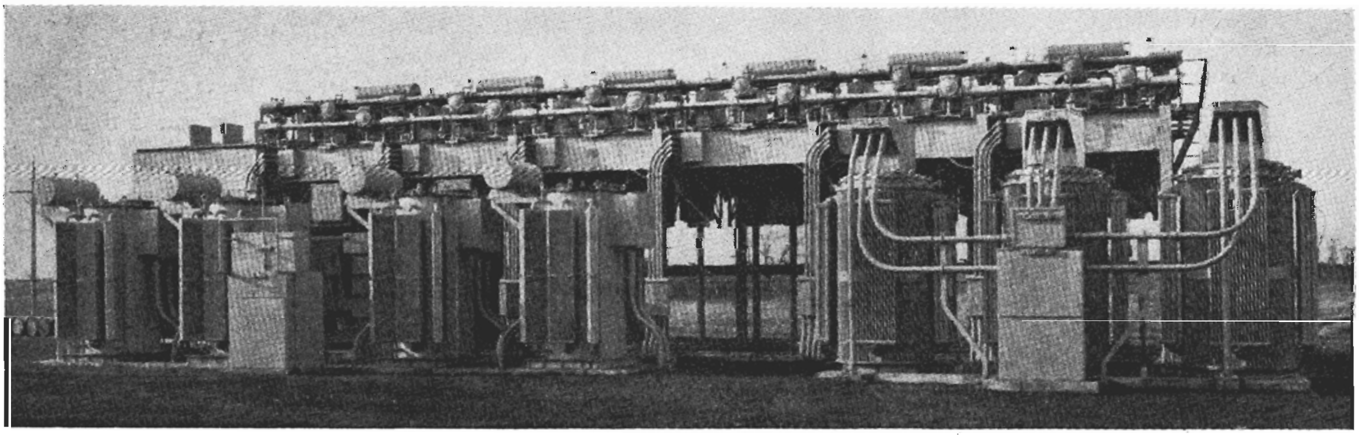




**PENNSYLVANIA POWER AND LIGHT CO.** began radio noise investigation work in 1924 to improve customer's radio reception, and has been active in this field ever since. The search for mitigative measures to permit isolation of quiet sections of line from noisy sections led to a cooperative development and application of line type radio frequency choke coils, the experimental installation of which is shown above.

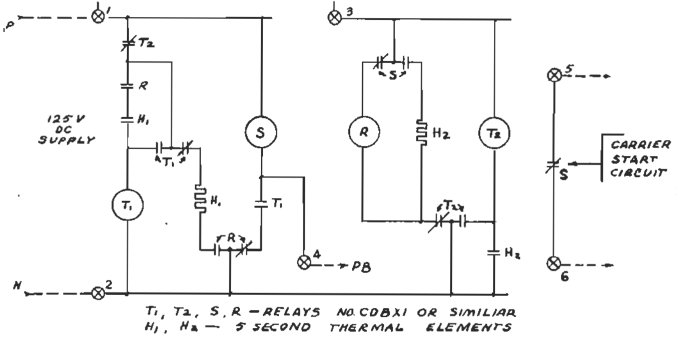
1930 — **THE CONSOLIDATED GAS, ELECTRIC LIGHT AND POWER CO. OF BALTIMORE** initiated its use of high voltage fuses to protect transformers tapped from a high voltage ring around the city. Here is a typical installation showing the special type of 110-kv fuse holder, development of which increased safety to personnel when replacing fuses and reduced the time required for this operation, especially in bad weather.



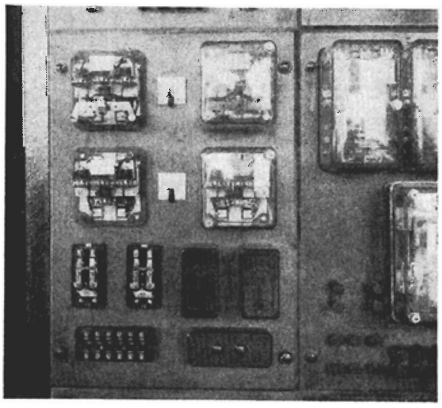


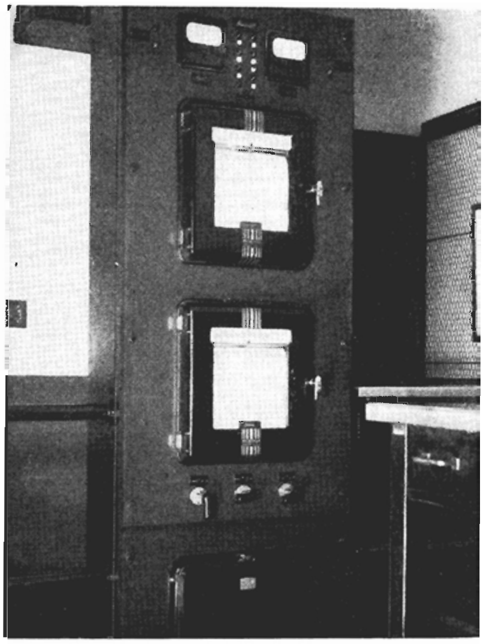
1930 — **THE PUBLIC SERVICE CO. OF NORTHERN ILLINOIS** was a pioneer user of outdoor metalclad switchgear. This 33-kv installation shows the metalclad design enclosing transformer connections and disconnect switches. This type of gear provided greater safety and reliability, higher salvage value, reduced space requirements, and lowered overall cost.

**GULF STATES UTILITIES CO.** uses the unique relay scheme shown below at unattended carrier terminals to actuate automatically and time return signals on receipt of a carrier check signal from an attended station.

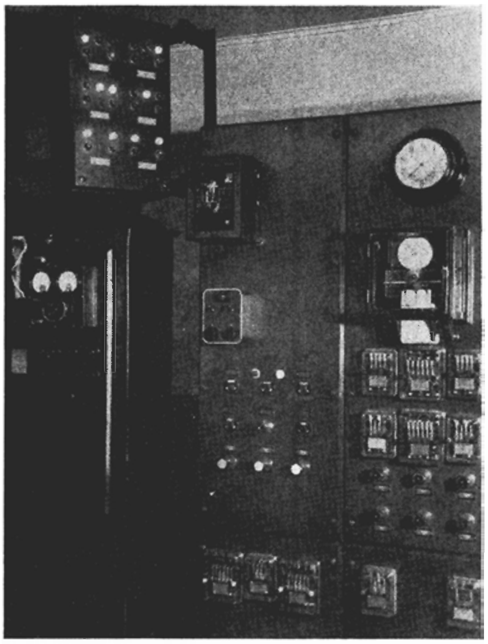


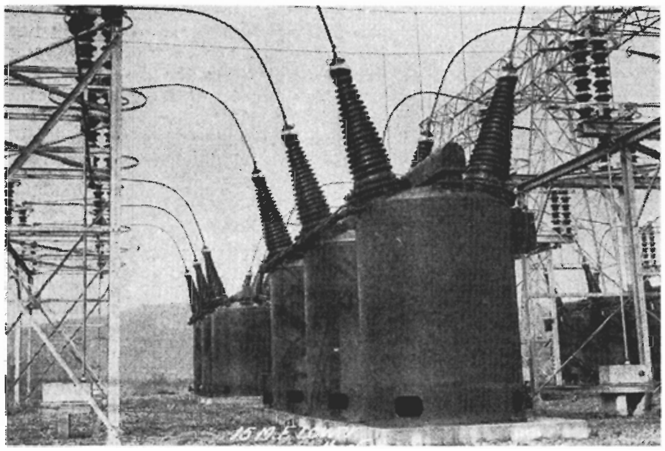
1939. A scheme developed by engineers of the **GULF STATES UTILITIES CO.** automatically blocked tripping of interconnections between two power systems under out-of-step conditions. In addition, selective tripping was provided under fault conditions. Both features were obtained with existing impedance relays and without use of carrier current or pilot wires. A typical relay installation for this purpose is shown at the right.

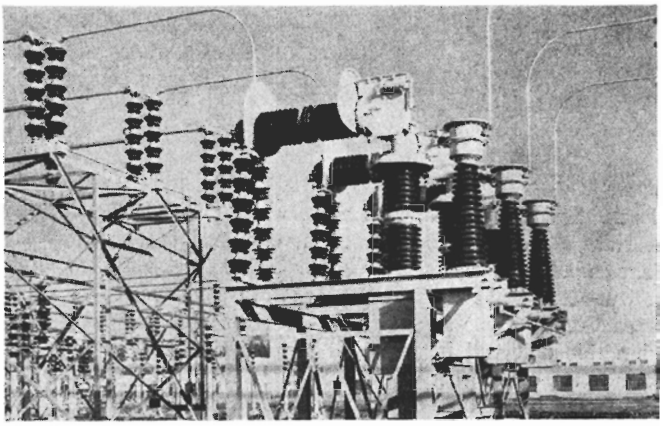




Pioneering work on system load control by the **DUQUESNE LIGHT CO.** was initiated with the installation of the first recording frequency meter in 1925, on which control contacts were provided and schedules set up to provide for relief of system load in the event of low frequency. In 1930, interconnected operation of this company's system required tie-line control rather than frequency control, and the equipment shown on the left was provided for this application. Program load control, right, was developed and installed in 1932 to provide complete automatic load scheduling on six governed turbines, from minimum to maximum station load. The comprehensive load control equipment now employed on this system minimizes rapid variations in tie-line load or system frequency.

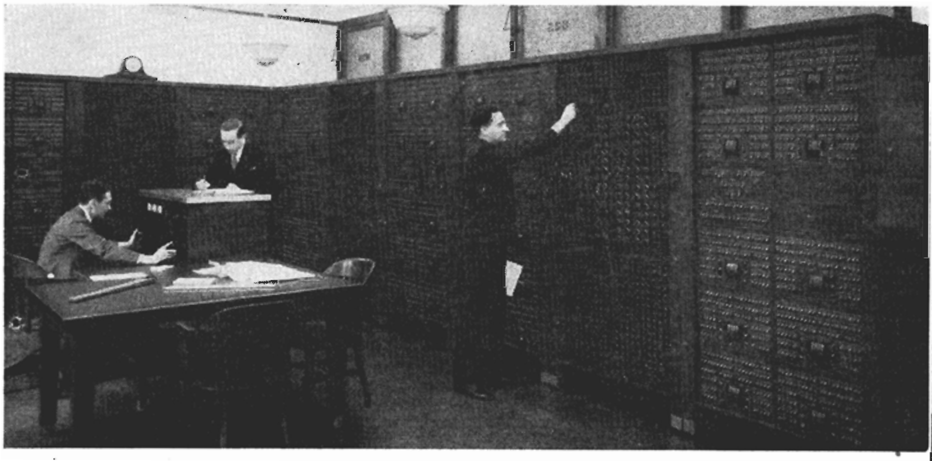




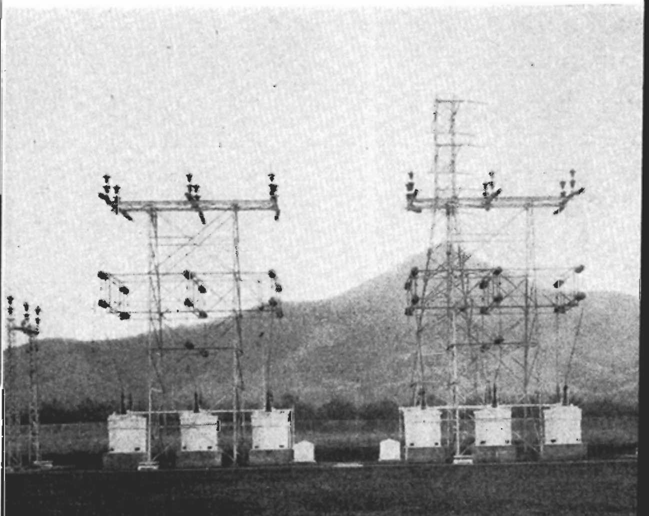


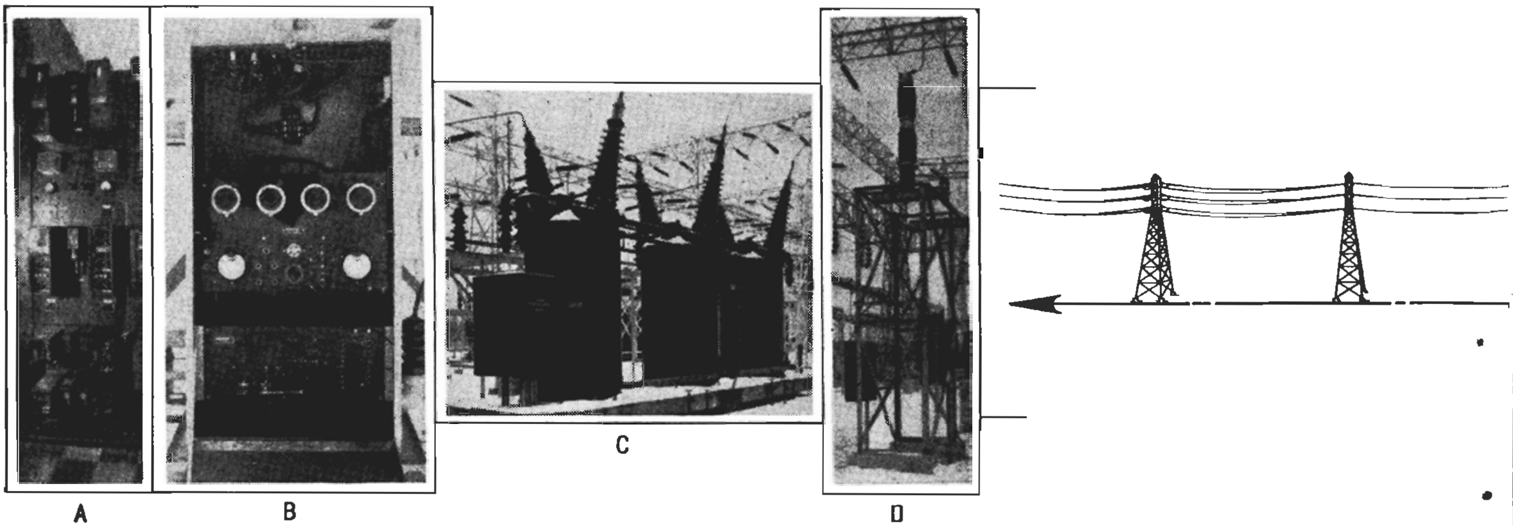
The first eight-cycle high voltage circuit breakers (above left) were installed on the **NEW ENGLAND POWER CO.**'s system in 1930. By 1936, three-cycle breakers similar to those shown above right were installed on the transmission lines delivering Boulder Dam power to Los Angeles. The rapid clearing of faults, made possible by the development of high-speed, high-voltage breakers such as these, permitted a considerable increase in the amount of power which could be transmitted from a given circuit and still maintain stable system conditions when line disturbances occurred.

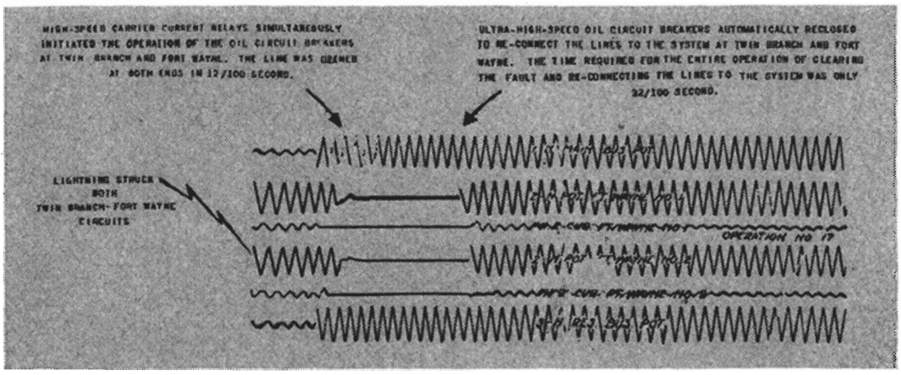
1932 — **COMMONWEALTH EDISON CO.** was the first power company to install the a-c network calculator, needed to analyze electrically the problems involved in complex electric power systems. This equipment, shown below, has been continuously used since its installation and has proved invaluable in system planning.



1929. This substation of the **PACIFIC GAS & ELECTRIC CO.** is a tie- in point with the **COAST COUNTIES GAS & ELECTRIC CO.** The two 110-kv circuits operate on an automatic synchronous reclosing system. Synchronous conditions must exist before the automatic reclosing equipment will permit a reclosure following circuit interruption. By this means, the time of service interruption on this important interconnection is kept to a minimum.







**The development of high-speed switching, high-speed carrier current relaying, and ultra-rapid circuit breaker reclosing on transmission lines of the AMERICAN GAS AND ELECTRIC CO. have been important tools in integrating the present central power system. Relay operating time has been reduced from more than a second to 17/1000 seconds and oil circuit breaker time from about 1/3 second to 6/100 seconds. Shown at the top, above, are the essential elements of the relaying and switching setup; A & H, protective relay equipment; B & G, carrier transmitter-receiver equipment; D & E, high voltage coupling capacitor equipment. The automatic oscillograph record (left) shows the time required for ultra-high speed switching equipment to disconnect a 132-kv line from the system and reconnect it after the trouble is cleared.**

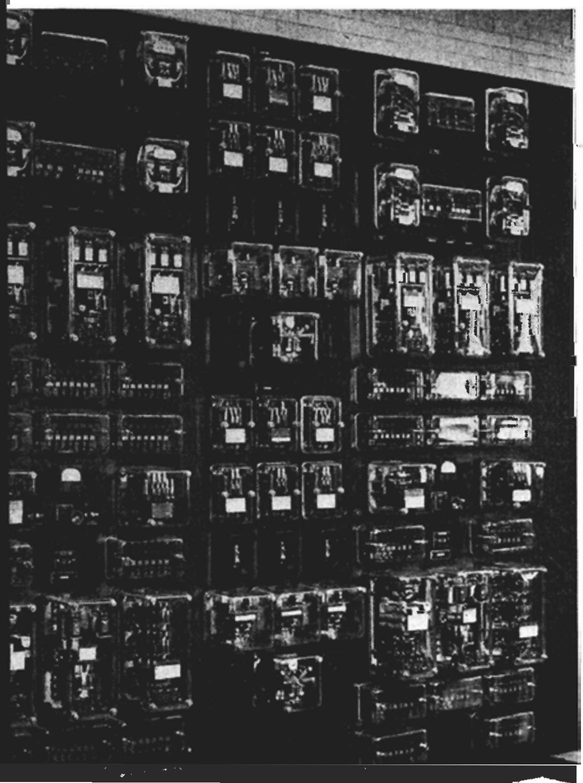
loads. Series capacitors also are used to perform the work of a voltage regulator for normal increase and decrease in load. The importance of series capacitor applications is indicated by a Duquesne Light Co. installation of a 10,000-kva, 66-kv series capacitor on a line supplying a steel plant load. It is expected that this unit will be instantly effective in correcting voltage dips to the extent that would only be matched by a synchronous condenser of 30,000 to 40,000 kva capacity operating with fixed field.

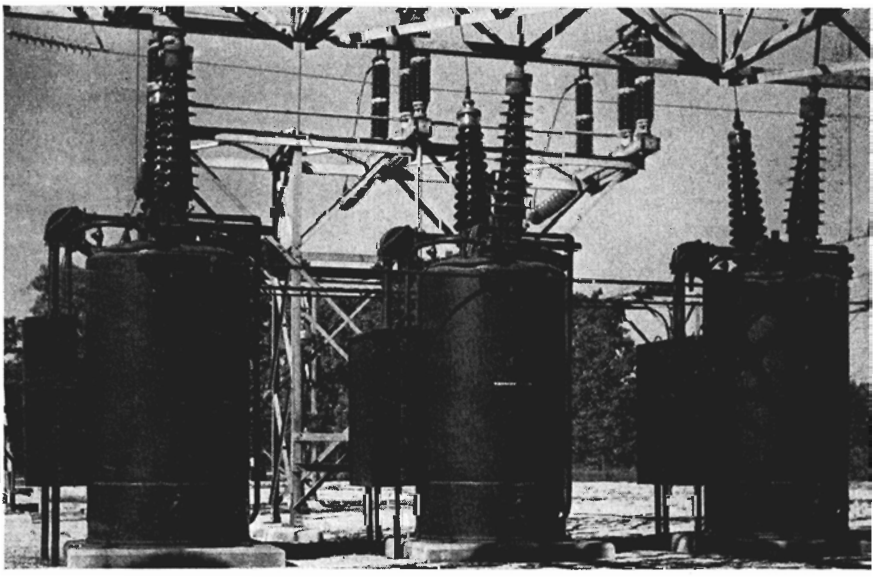
### AUTOMATIC SWITCHING

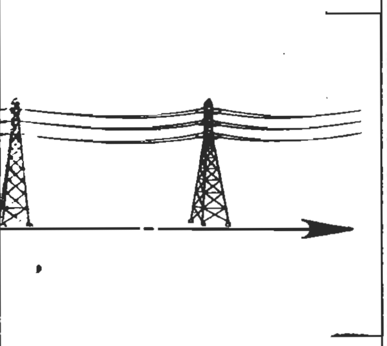
Progress in the development of automatic switching equipment made it possible for the power companies to effect important improvements in system service by the use of unattended, fully automatic power distribution substations. Another step in the direction of improved service was the development of supervisory control equipment for the remote control of unattended stations. Company-owned or leased channels were

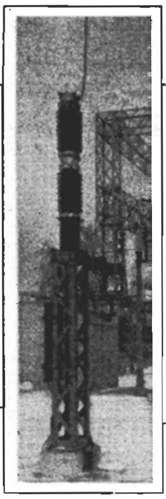
*(Continued on Page 268)*

**The PUBLIC SERVICE CO. OF INDIANA has for some years been working on single-pole relaying and reclosing on its extensive 132-kv system. The incentive was recognition of the increased permissable loading of transmission lines which would be possible if only an individual phase were opened under single-phase fault conditions, instead of tripping all three phases. Shown below is one of the 132-kv single pole reclosing breakers on this system. The photo at the left shows the panel arrangement of carrier pilot relays required to provide this type of protection on two circuits.**









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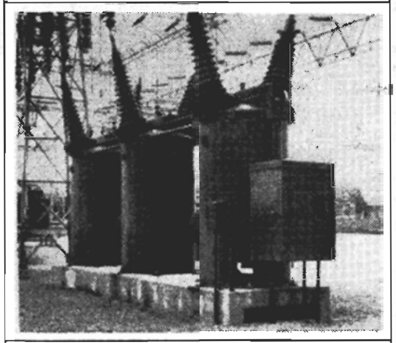

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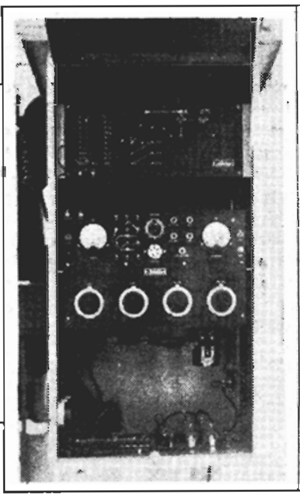

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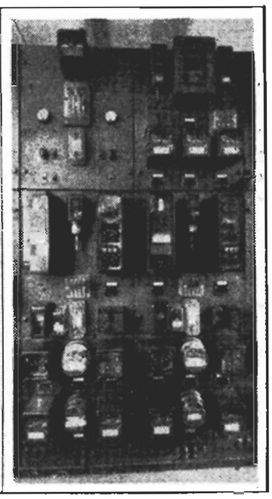

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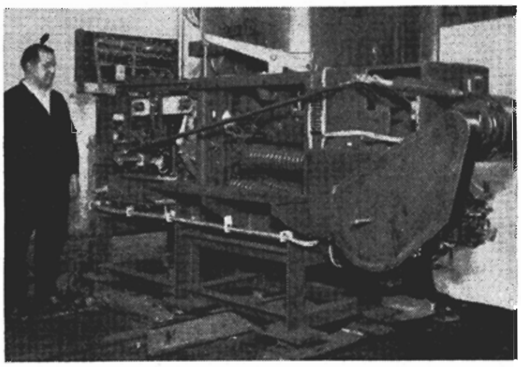
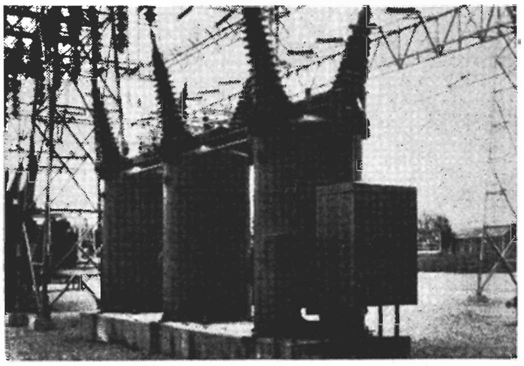
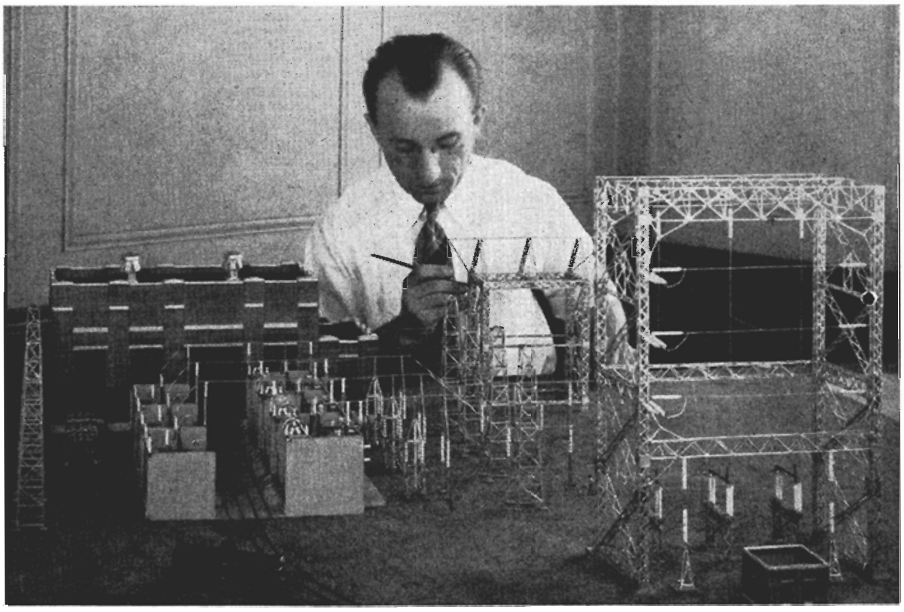


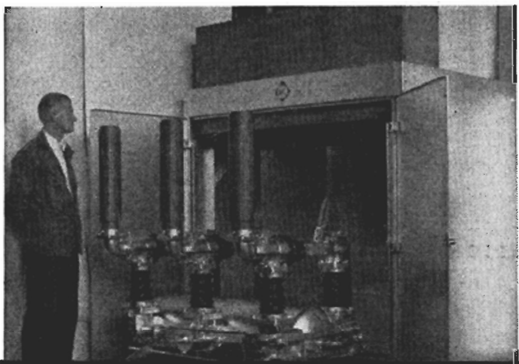
On the left is the huge, cumbersome and expensive operating mechanism first developed for ultra-high speed reclosing of oil circuit breakers on transmission lines of the **AMERICAN GAS & ELECTRIC CO.** The relatively small cabinet at the end of the outdoor oil circuit breaker on the right houses an ultra-rapid reclosing mechanism of present-day design.

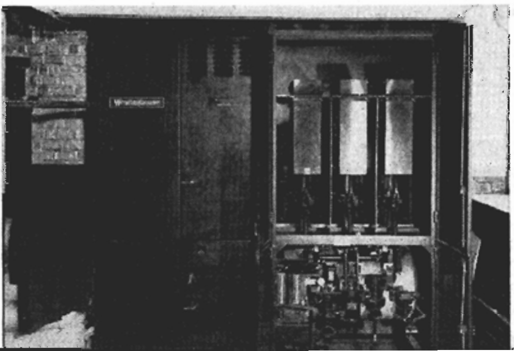


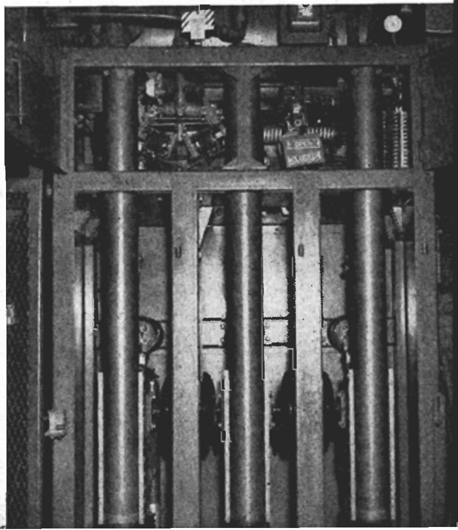
This model of the terminal station for the **COMMONWEALTH EDISON CO.**'s 220-kv transmission line was built by a member of the company's engineering department. Building of scale models, prior to construction of the actual station, is of considerable assistance in solving station design details. In this model, the scale is 1/8 inch to one foot. The actual height of the tower at the right is 125 feet.



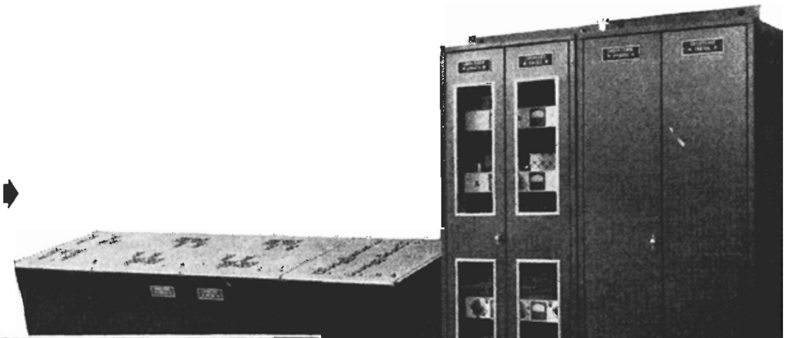
Introduction of air circuit breakers for power station applications eliminated the fire hazard incident to the previous use of oil circuit breakers. The General Electric air-blast breaker at the right was installed by the **CONSOLIDATED EDISON CO. OF NEW YORK, INC.** in 1939. The center view shows the Westinghouse compressed air breakers installed by the **OHIO EDISON CO.** in 1940. Shown at the left is a cubicle type air-blast circuit breaker of Allis-Chalmers Mfg. Co. design. All of the breakers shown in these views are rated at 1,200 amp, 15-kv, 500-mva interrupting capacity.

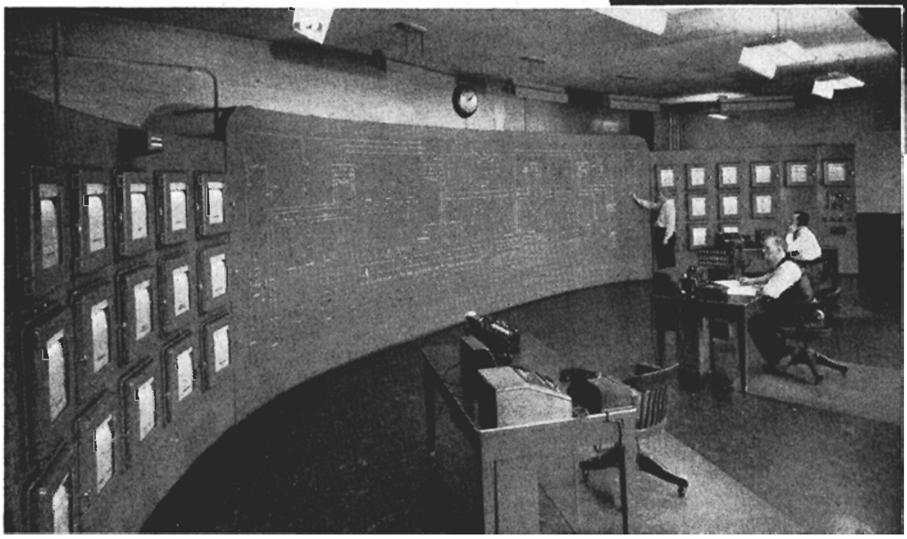




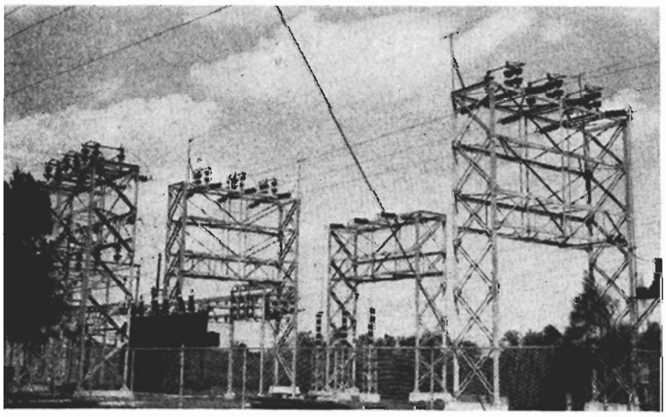


**1947—Equipment to operate through the medium of carrier current superimposed on transmission lines of the IDAHO POWER CO. is now being installed to provide remote control, from a centralized point, of a number of high-voltage switching stations. Mounted on the benchboard on the left are the control escutcheons, with miniature bus, and master control keys. Cabinets on the right house the carrier current transmitter-receiver equipment and the supervisory control relay equipment for installation in the dispatcher's office. This installation represents the most modern method of coordinating system operation by placing equipment control directly at the fingertips of one man familiar with prevailing system operating conditions.**

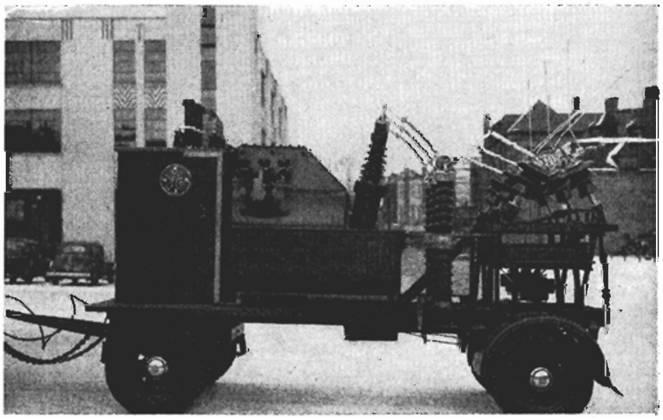




**This installation on the system of the LOUISVILLE GAS & ELECTRIC CO. is an excellent example of modern facilities for system dispatching. The system diagram is in the center, the megawatt and reactive megavoltampere recorders at the left and right, and the automatic load frequency control equipment at the extreme right.**



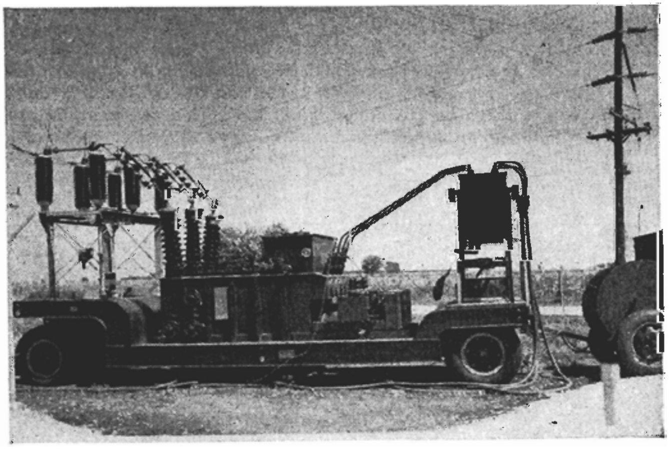
**The FLORIDA POWER CORP. has adopted standard steel structures shown above for substation construction. These self-supporting frameworks provide great flexibility of design and maximum economy in steel usage.**



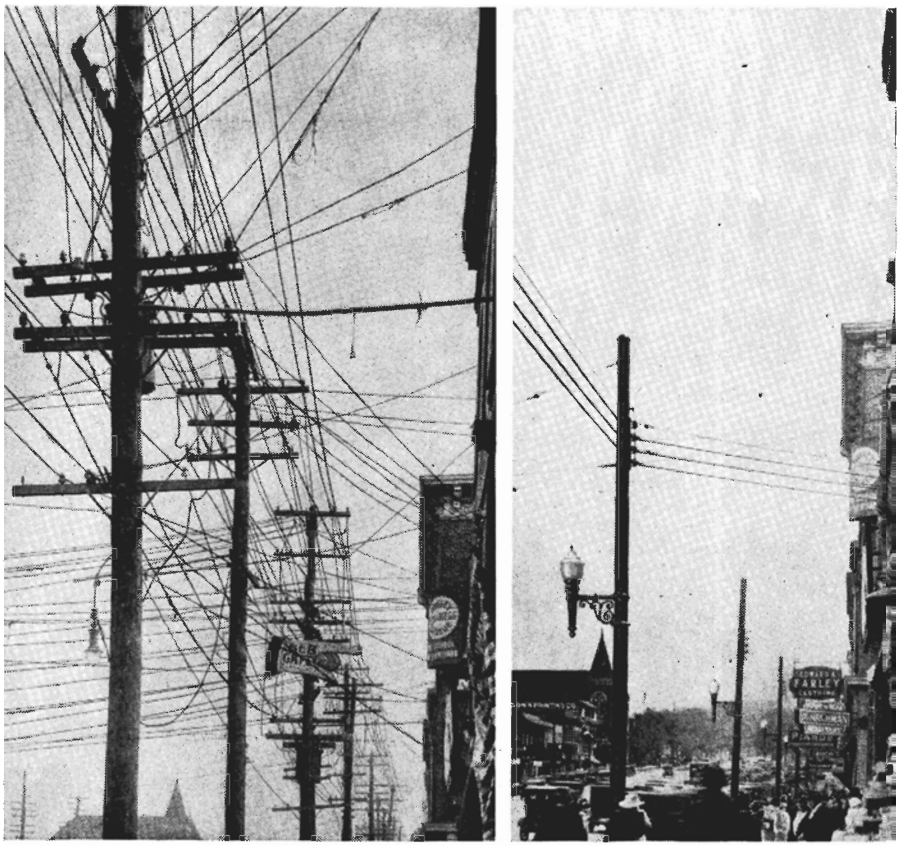
**One of the first mobile substations placed in service is shown above. It was built for the CENTRAL NEW YORK POWER CORP., and can be operated on 44-kv, 22-kv, or 12-kv, to supply 2300/4160 or 4600 volts. The portable substation below, in service on the CENTRAL ILLINOIS PUBLIC SERVICE CO.'s system, has a range of voltage up to 66-kv, with a capacity of 1,500 kva. Mobile substation units such as these have proved invaluable in minimizing outage time in emergencies and in facilitating reconstruction and routine maintenance of substation equipment.**

utilized for this equipment. A still later development has permitted the use of a carrier current channel for control purposes. An early application of carrier current type control was made by the Bangor Hydro-Electric Co. in 1938, when equipment of this type was installed for the remote control of 33-kv air-break switches on that system. This installation made possible the quick isolation of trouble on a branching transmission system, and materially reduced the duration of interruptions.

Although a number of the changes which took place in system protection techniques during the early days of power system development could be considered revolutionary in character, the developments of more recent years have proved to be of an evolutionary nature. Major improvements in the performance and economy of our power systems have resulted and may be expected to continue.



# Urban Distribution Progress



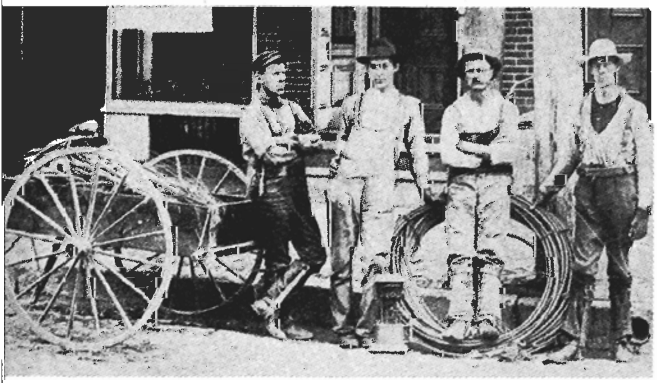
**Yesterday and Today—Rapid, but haphazard, growth of distribution circuits often resulted in heavily loaded pole structures which formed the unsightly arrangement shown on the left. In congested, urban areas power company engineers turned to underground circuits and alleyway overhead construction as a means of improving appearance. Also important was the redesign of structures to emphasize neatness and safety. The view at the right shows the same street areas as that on the left, after distribution circuits had been relocated and the street lighting system modernized. This comparison typifies the contribution of the distribution engineer toward improved appearance and better service in the past quarter century.**

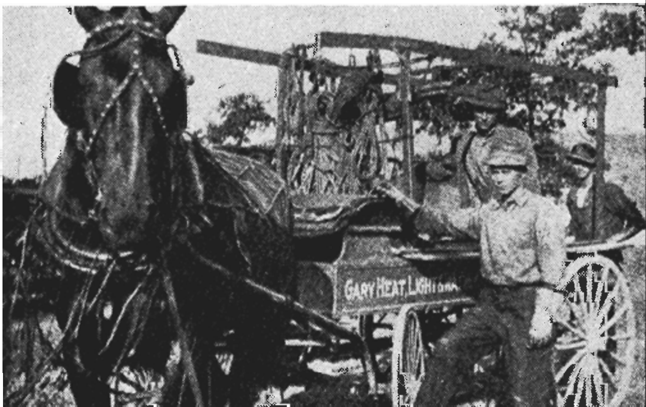
MORE than half the invested capital of the power industry has been spent on the distribution system. Power distribution has presented major engineering problems from the very first days of the industry. The Edison d-c system, being of low voltage, had very definite limitations, which took the form of high investment in conductors and restricted geographic service areas because of voltage losses due to resistance drop.

George Westinghouse, who pioneered the alternating current type of distribution system at Great Barrington, Vermont, in 1886, set the pattern for the modern form of electrical service wherein power is transmitted from power stations to load areas at high voltage and transformed to lower voltages for use on the customers' premises. This was the first major step in reducing the costs of distribution.

Subsequent developments, many of which are pictorialized on the following pages, have gone far to improve the reliability and quality of service, to improve appearance, and reduce the investment costs of the modern distribution system. High on the list of important contributions to these ends will be found low voltage a-c network equipment, unit type substations, aerial cable, reclosing breakers and fuses, voltage regulation devices and capacitor units. Most of these have been developed in the past quarter century, when electricity became widely used for services other than lighting. Future applications of electricity likely will require even further refinements in service and will certainly involve an increased capacity of service facilities for all classes of consumers. Distribution engineers, therefore, can expect to be called upon to provide a more comprehensive service without disproportionate incremental investment costs.

*Photos courtesy J. R. Kearney Corp.*





**As distribution circuits were not extensive in the early days, this trouble crew very likely could provide satisfactory emergency service with only a hand cart as a transportation medium. Greater mobility became necessary for line crews as systems grew, and the horse and line wagon became standard equipment. Lower right, view of a crew of a predecessor company of the NORTHERN INDIANA PUBLIC SERVICE CO. Below left, the line crew of the SOUTHWESTERN GAS & ELECTRIC CO. in 1906. That company now has 15 modern line crews to handle construction and emergency work involved in servicing 110,000 customers.**

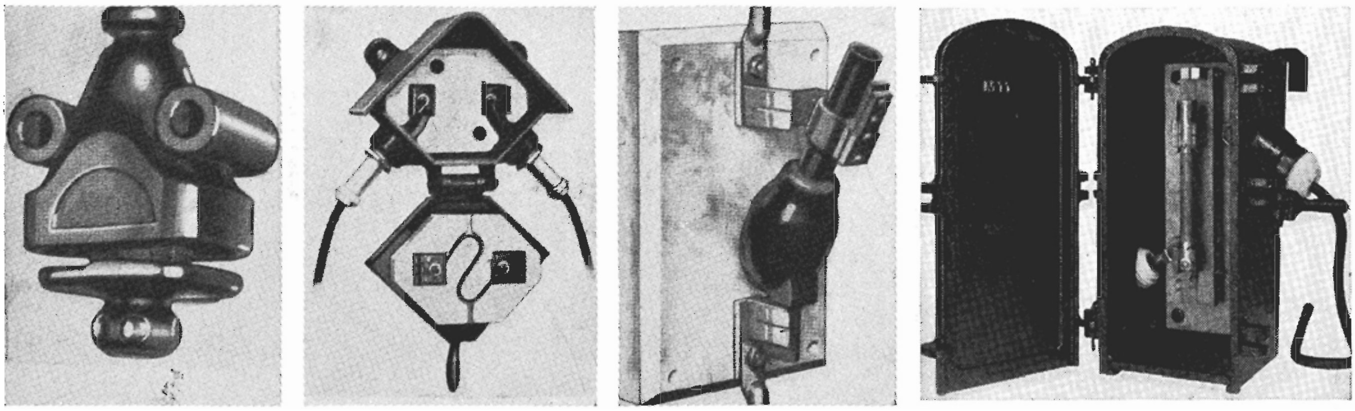
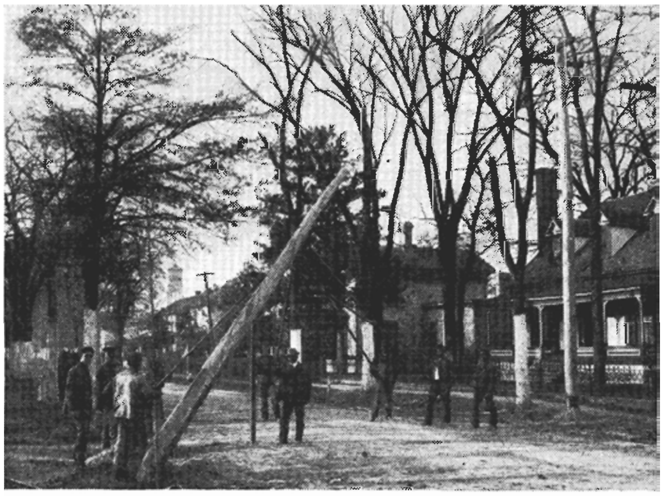


*Photo courtesy J. R. Kearney Corp.*

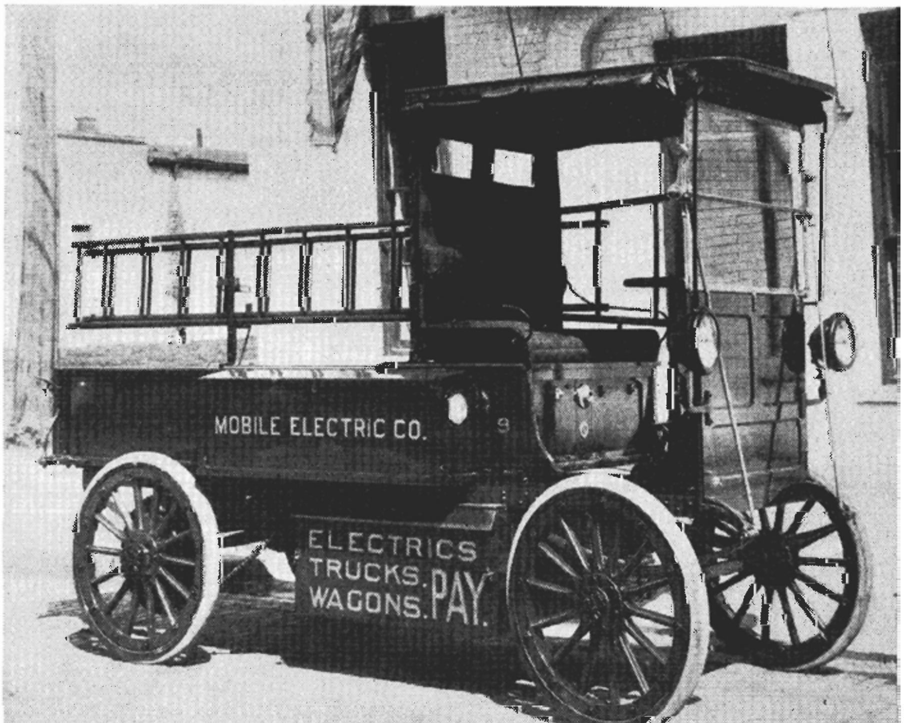
*Photo courtesy W. N. Mathews Co.*

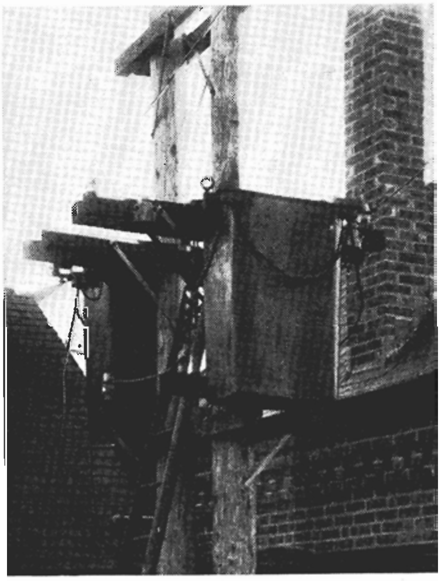
**The need for protective devices on overhead lines became manifest shortly after the initial operation of the first distribution system. Shown above is the development of primary cutout design. Primary cutouts are used to give fuse protection to equipment and circuits. Reading from left to right, early plug type cutout in use at the turn of the century. In this device a lead fuse wire was inserted in the plug and the plug pushed into the cutout receptacle, completing the circuit through the fuse wire and appropriate contacts. The next fuse is an improvement, offered in about 1906, which incorporated cast iron housing and a porcelain base plate with a door-opening type of contact mechanism. Neither of these early designs made provisions for arc extinction, so that satisfactory operation under heavy short circuit was questionable. The next two photographs show designs of about the same period which made provision for handling the gases from a fuse blowing. One provided an enlarged "explosion chamber" and the one on the extreme right took advantage of the value of horn fiber as a de-ionizing agent. In the latter design the fuse was mounted in a cartridge which in turn was clipped to a wooden switch blade carrying the main contacts. Removal of the wood block assembly provided an effective disconnect for the circuit and the fuse element was a tube through which the fuse wire was threaded. It was the forerunner of the modern expulsion type cutouts.**



**Early line crews set structures with pike poles and manpower. This crew is setting up a distribution system in a North Carolina town in the early 1900's.**

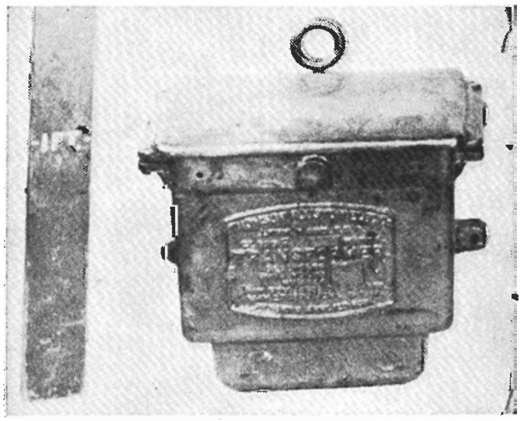
**Old Dobbin was displaced by mechanically powered vehicles early in the industry's history. Electric companies, naturally, were greatly interested in electrically operated vehicles. These provided a load during the night charging period when generators were lightly loaded. This was the latest thing in line trucks in 1914. The photograph was furnished by the ALABAMA POWER CO., which now serves Mobile.**

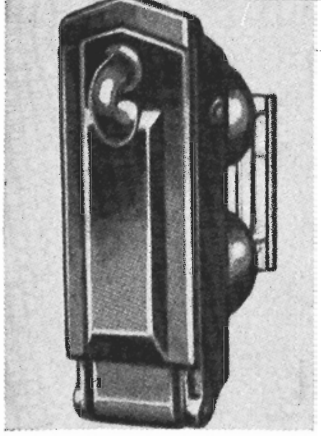


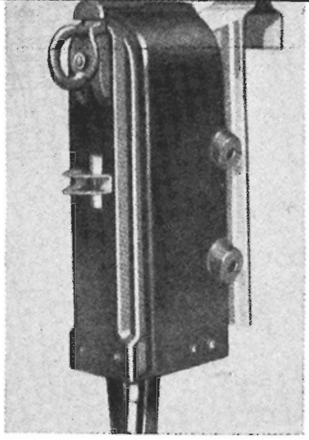


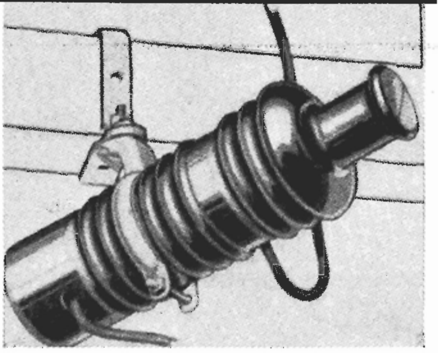
**The mounting of distribution transformers on poles was an early practice. This view shows two Wagner type "M" transformers installed on the system of the PLYMOUTH (Mass.) ELECTRIC LIGHT CO. in 1907. Note the use of glass insulators and plug type cut-outs.**

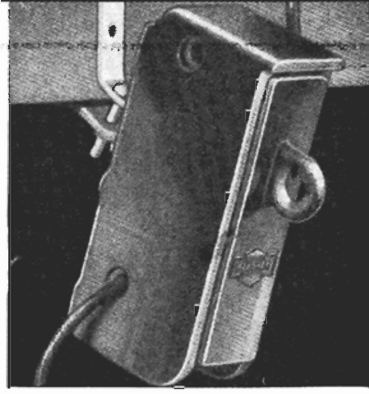
**Below, early transformer of about 1890, operated in either air or oil, about one foot square. It could be suspended from a single ring lug and is indicative of the small electrical requirements of early consumers.**



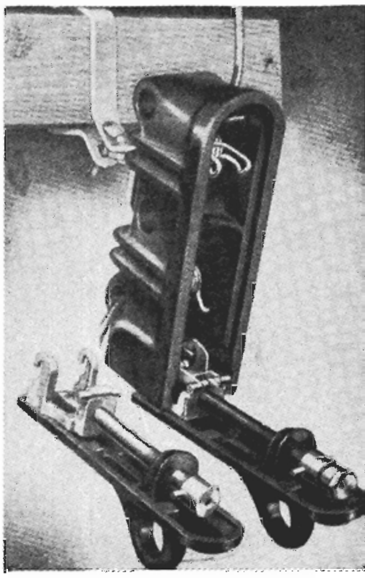






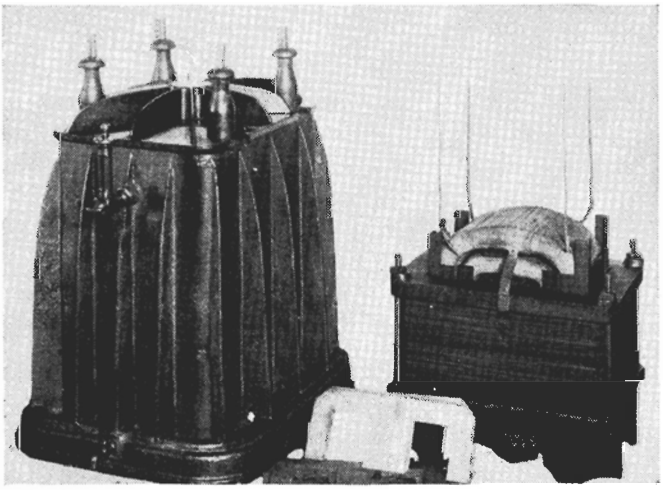


*Photos courtesy J. R. Kearney Corp.*

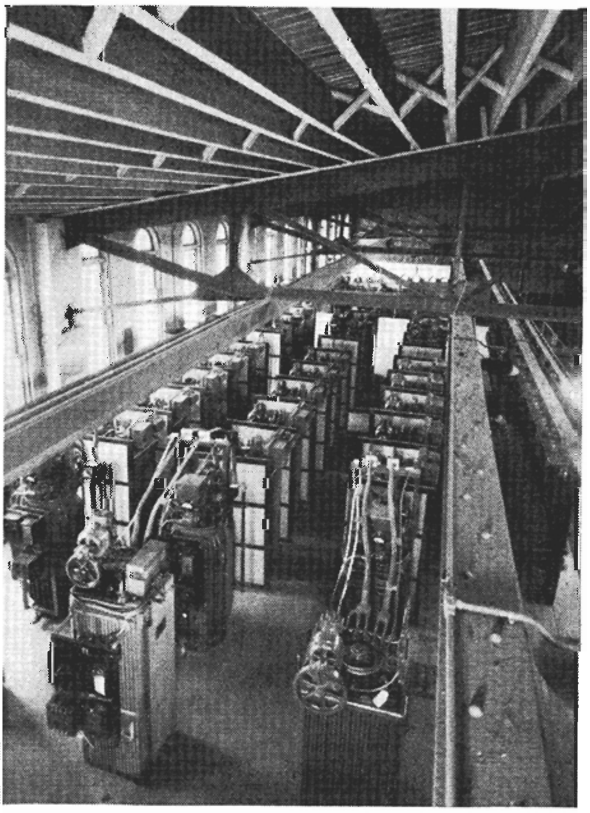


**About 1914, cast porcelain type housings became universally used, together with a tube type fuse mounted on the door, similar to the design shown above left. Another interesting design was the "throttle" type of cutout shown above, in which the fuse was contained in a telescoping tube, the sliding portion of which moved under short circuits as an arc extinction device. The difficulty of this device was the inability to keep dust, corrosion, etc., from affecting the working parts. A new design, utilizing extruded wet process porcelain, returned to the plug type principle by incorporating arc extinction and safety features, as well as ease of installation. The two fuses at the extreme right are cutouts which incorporated improved circuit interrupting features, together with indication of the faulted line, through the drop-out principle. The fuse mechanism is so arranged that, when blown, the door drops open, thus showing which circuit is faulted and thereby speeding identification of trouble and restoration of service.**

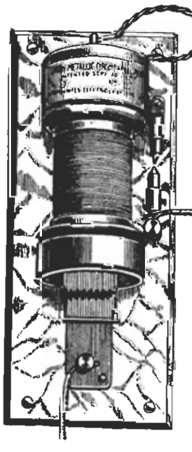
*Photo courtesy Westinghouse Electric Corp.*



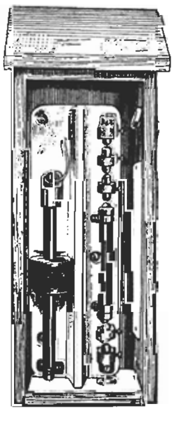
**The transformer shown left, used in the first high voltage power transmission system, was the first oil-filled design and was installed on the 10,000 volt transmission system at Pomona, Calif. Units like these stepped generator voltage to 10 kv for transmission and reduced it back down to primary distribution voltage at the load area. As there was some doubt as to the ability to wind transformers for this voltage, ten 6-kw units were used in series at each end of the line. Today transformers are under construction for 500,000 volt service.**



**Voltage regulation on distribution feeders was an early practice on alternating current systems. The first voltage regulators were manually operated contacts in tapped windings of substation transformer banks (see page 258). Under this system the voltage of customer circuits was controlled by the substation operator. Early in this century the induction regulator was developed which gave smoother control over voltage conditions than was possible by the tapped winding method. Early induction regulators also were hand operated but designers soon added motor operating mechanisms which, with suitable relays, would provide automatic voltage control for distribution feeders. This refinement improved the quality of service on the customer's premises, giving better operation for appliances and uniform lighting with maximum lamp life. At the left is a section of a substation on the PUBLIC SERVICE CO. OF COLORADO's system showing automatic induction voltage regulator bays which were incorporated in the station design about 1915. As the station grew, additional regulators of a more modern design, as shown in the foreground, were added.**



1892

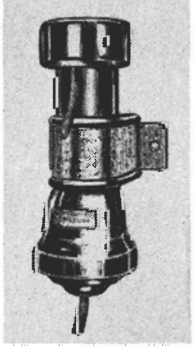


1909

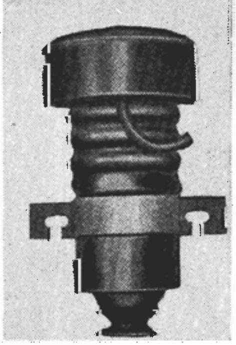
**Evolution of the lightning arrester for distribution circuits. Upper left, coil and gap type. Upper right, outdoor housing added. Below, expulsion type (left) and modern design (right).**

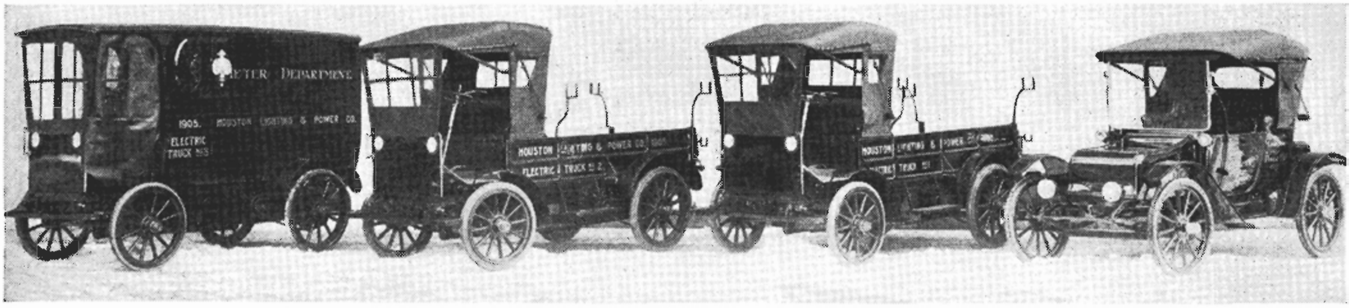
*Photographs courtesy Electric Service Supplies Co.*

1916



1926




METER DEPARTMENT
1905. HOUSTON LIGHTING & POWER CO.
ELECTRIC TRUCK
HOUSTON LIGHTING & POWER CO.
ELECTRIC TRUCK No 2.

**Distribution fleet of the HOUSTON LIGHTING AND POWER CO. as it appeared in 1912. All vehicles were electrically propelled. Power companies in the early days were active promoters of electric vehicles because they provided the possibilities of increased load through battery charging stations.**

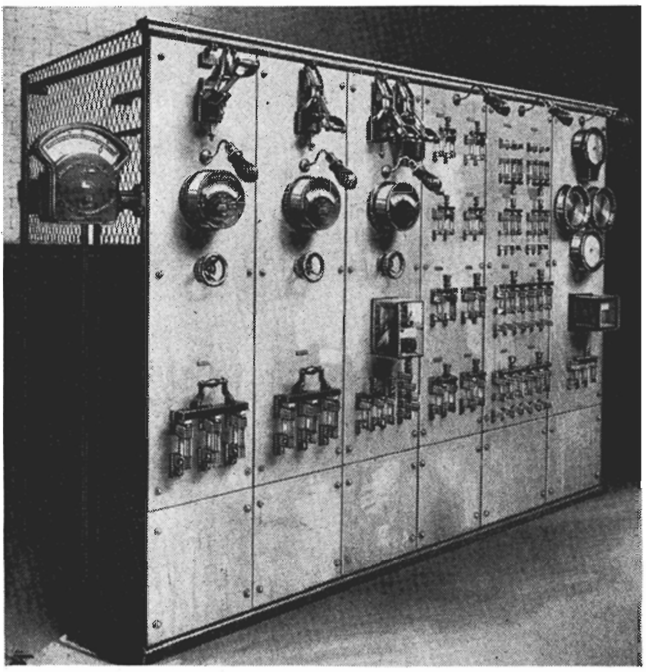
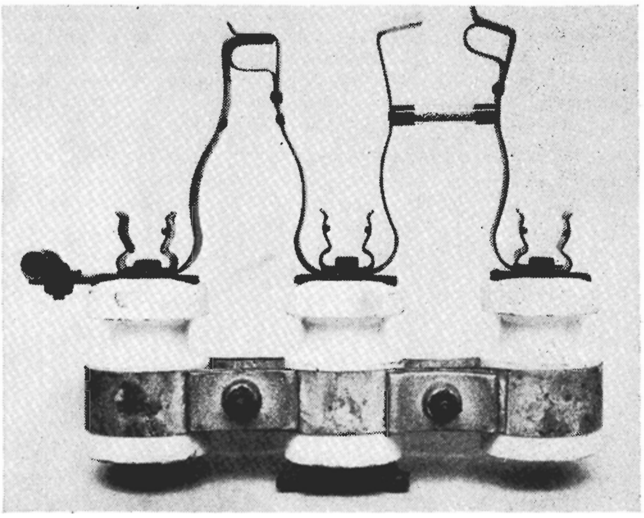


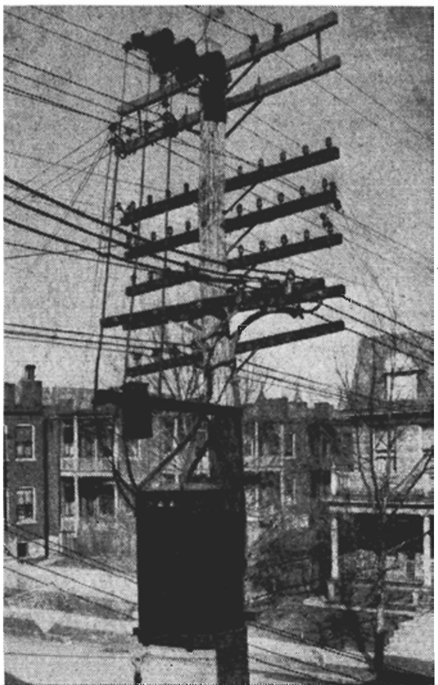
*Photo courtesy Trumbull Electric Co.*

**Industrial switchboards for power distribution within a customer's plant looked like this in 1907. Of particular interest are the old style, hand operated air circuit breakers shown at the top of the three left-hand panels.**

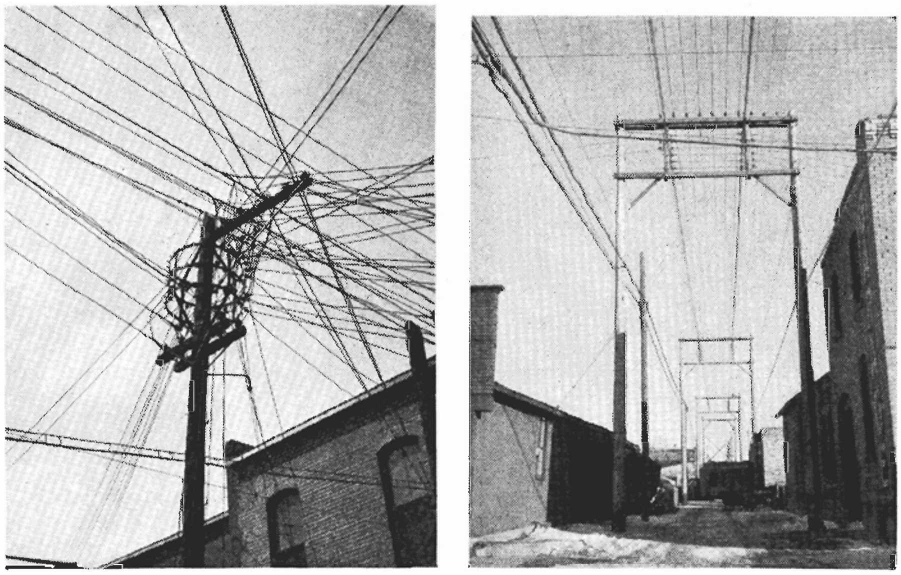


**Believe it or not, this is one end of a pioneer repeating fuse development used by the SAN DIEGO GAS & ELECTRIC CO. It represented one of the first attempts to limit the time of customer outages by automatically inserting a second fuse into a faulted circuit. Used on 12 kv branch lines and at individual transformer stations, it consisted of a holder for three fuses, two of which were inoperative as long as the contact clips were separated by explosive cartridges as shown on the right. When the first fuse blew, the line voltage detonated the cartridge, allowing the contacts to close, and connecting the second fuse into the circuit. If this fuse blew, the operation was repeated, making third fuse operative. Thus the device provided not only a repeater fuse but also an indication of blown fuses. While crude as compared with modern designs, this development provided a successful early solution to the problem of better service and saved many trips for the troublemen of the system.**

**A move toward simplifying pole structures was accomplished when three single-phase transformers were incorporated into a single tank. This view shows a 150 kw, three-phase transformer on the UNION ELECTRIC CO. OF MISSOURI's system as installed in 1914. Note the special basket type hanger used to support the transformer.**

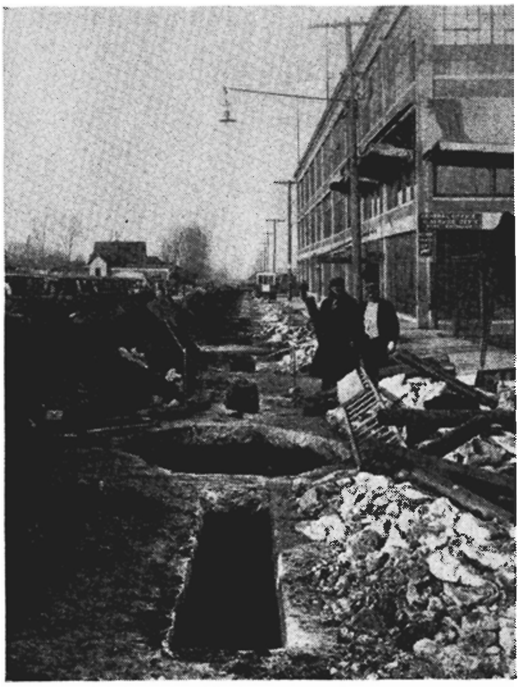


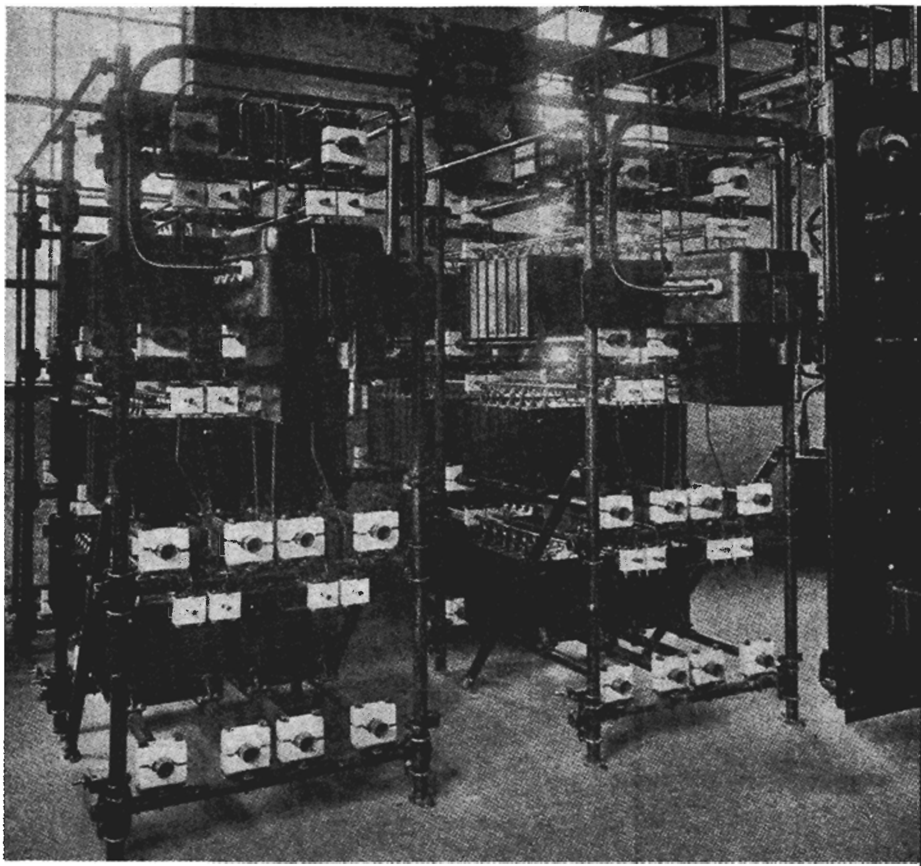
*Photos courtesy Hughes Bros. Inc.*



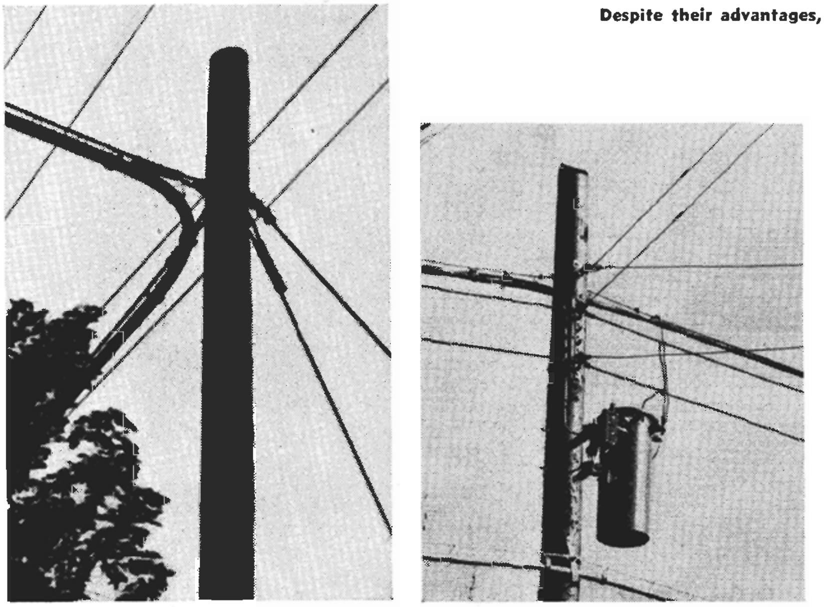
**Comparison of overhead construction practices in the '20's (left) and in the '40's (right). Note the old style ring take-off used in the early days to secure space for customer drops. The modern practice enhances appearance, safety, and service reliability.**

**As load densities increased beyond the capacity of overhead structures, circuits had to be placed in duct lines below the street. Underground construction was used for both important tie-lines between power stations and substations and also for distribution circuits in congested areas. Such construction involved high installation costs and required the development of equipment suitable for operation while submerged. This view shows an early duct line excavation in Kansas City for the KANSAS CITY POWER & LIGHT CO.**



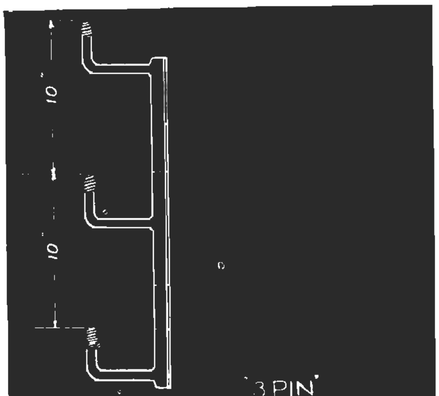


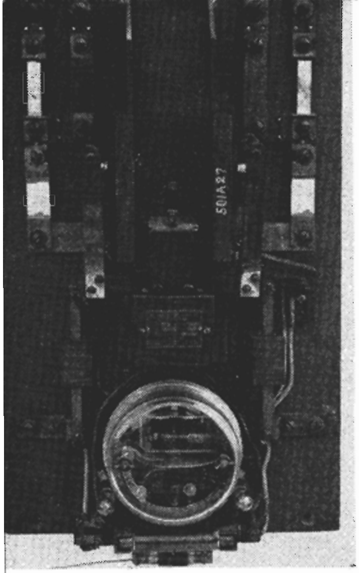
**Use of static capacitors to improve the carrying capacity and voltage conditions on distribution circuits is not as recent as many people think. The installation shown above was made by the BROCKTON EDISON CO. during World War I. Power needed to supply essential industries in one section of the system could not be supplied because of the length of time required to build additional feeders. As a remedial measure this 400-kva capacitor installation was installed at the end of the initial 13-kv transmission line raising the power factor at the terminal from 70 to 90 per cent, with a proportionate increase in the amount of useful power which could be transmitted over the circuit. Despite their advantages, capacitors were not widely used until the late '30's and during World War II.**



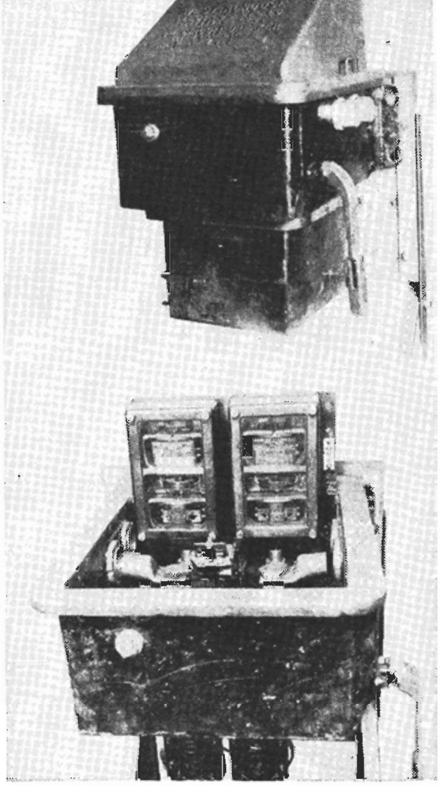
**Still another method of improving appearance and obtaining greater reliability for overhead distribution circuits involved the use of aerial cable, pioneered by the CENTRAL HUDSON GAS & ELECTRIC CORP. In this type of installation the three primary conductors are formed as a cable and supported on a copperweld messenger which serves both as a support and neutral conductor for the common neutral system. The installation above, right, shows the evident economies of the system which eliminates crossarms and insulators for the 4-kv primary circuit. The secondary circuit is carried on a rack directly above the transformer. Note the unit type transformer mounting directly on the pole. Above left is a 22-kv aerial cable installation of the DUQUESNE LIGHT CO., which also pioneered this type of construction. The successful solution of technical problems in these early installations has made for growing popularity of aerial cable.**

**1910—One of the early developments to improve overhead line appearance was the development of vertical supporting racks for secondary lines. Prior to 1910 it was universal practice to carry secondaries on cross-arms. Below is shown the drawing of a three-pin malleable iron bracket designed by the CONSOLIDATED GAS ELECTRIC LIGHT & POWER CO. of Baltimore. Now a universal practice, the vertical racks lessen congestion on poles, facilitate service connections and make identification of primary and secondary conductors easy.**

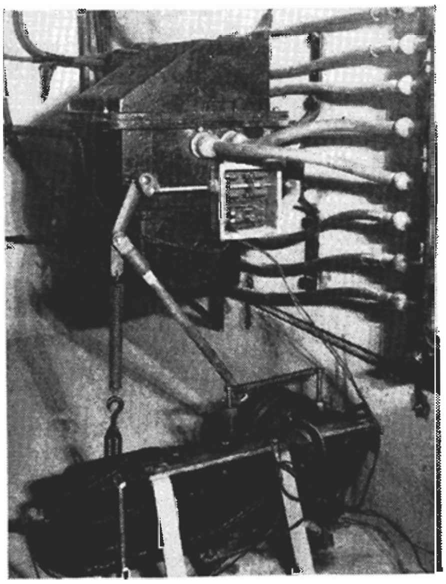


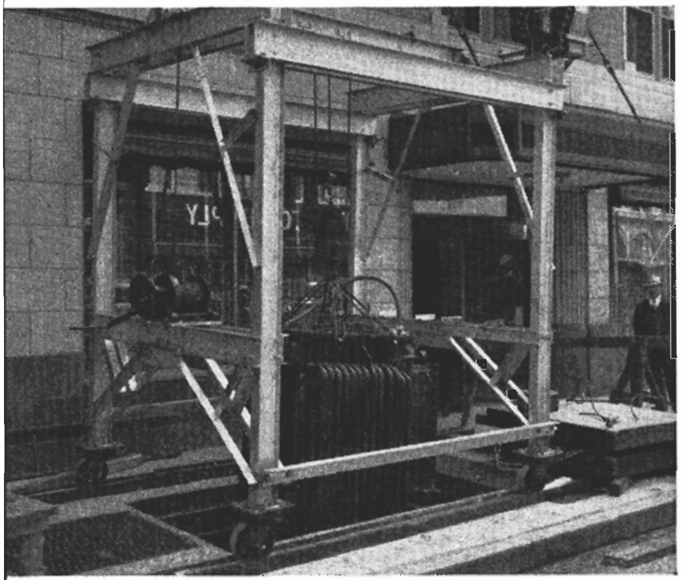


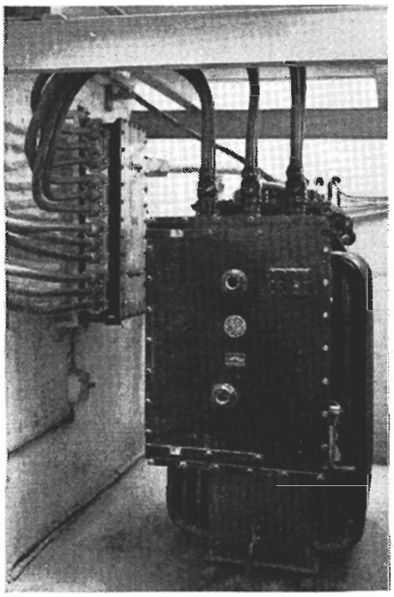
Because of potential economies, designers sought ways and means of making a-c underground circuits as reliable as direct current. This lead to the development of the a-c underground network wherein each customer enjoyed the advantages of multiple sources of power supply. Isolation of faulted network transformers and sections of primary cable was necessary to prevent a general outage on the cable network. This in turn led to the development of the network switch or protector. At the left is shown one such switch developed by the **CONSOLIDATED EDISON CO. OF NEW YORK, INC.** and placed in service in 1922. In the event of feedback or reverse power flow, indicating trouble in the primary supply, the relay opened the switch, disconnecting that primary feeder from the network. On secondary network cable faults, all protectors remain closed, the fault current burning the cable clear. Unless the fault is in a customer's service run, the opening of one point on the cable network does not affect service to any customer served from the network. Commercial equipment of this type was made available by Westinghouse Electric Corp. the same year.



Another experimental design of a network protector, developed by the **PUGET SOUND POWER & LIGHT CO.** in the early '20's consisted of adapting reverse power relays to a conventional waterproof oil circuit breaker as shown above. With this switch, manual reclosing was necessary in the event it tripped off the line. Below is a further development showing the adaptation of an automatic reclosing mechanism which would restore service after conditions became normal.



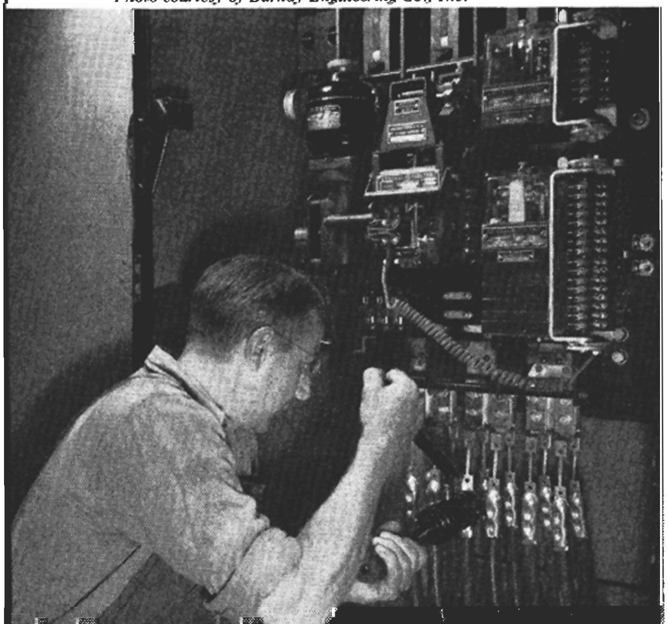




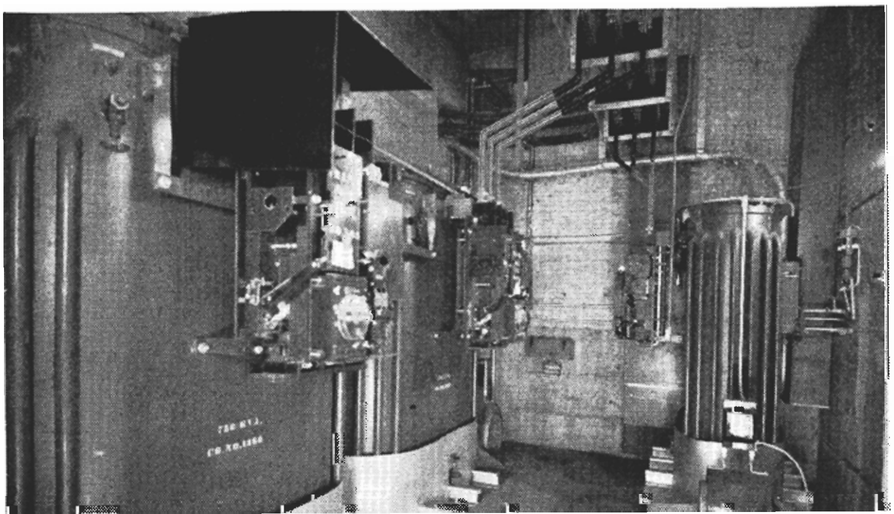
Close collaboration between the manufacturers and power companies soon developed standardized network equipment including junction boxes, disconnects and transformer-network units such as shown above. At the left, the transformer and network protector are being lowered in the sidewalk vault on the system of the **KANSAS GAS & ELECTRIC CO.** in Wichita. At the right, above, is the unit in place in the vault showing the network switch and junction box from which the low voltage a-c network cables emerge.

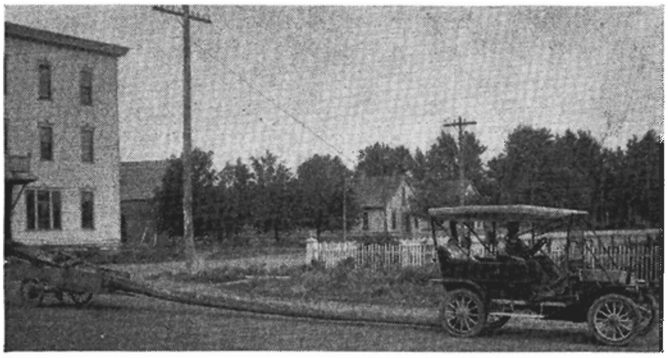
Early practice on a-c underground systems was based on burning the cable clear in cases of secondary cable faults. A later development, pioneered by the **CONSOLIDATED EDISON CO. OF NEW YORK, INC.** and the **DUQUESNE LIGHT CO.** provided for a limiter link designed to melt before any currents could damage the cable too greatly. In the installation shown below these current limiting links are being pressed on secondary cables connected to a modern network protector.

*Photo courtesy of Burndy Engineering Co., Inc.*



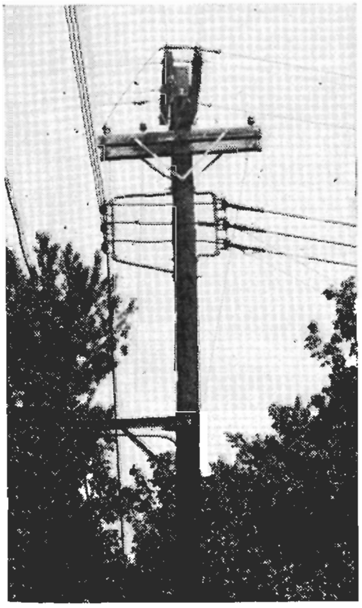
**DALLAS POWER & LIGHT CO.**, one of the pioneer users of the underground secondary network, also pioneered in the use of 13-kv feeders thereby eliminating one step of the transformation from transmission voltage to the customer service voltage. The photograph below shows a bank of three 750-kva, water-cooled transformers with open type network switches used when submersion is improbable. Underground networks, while costing much more than overhead distribution of equivalent capacity, provide reliability of service of a high order.

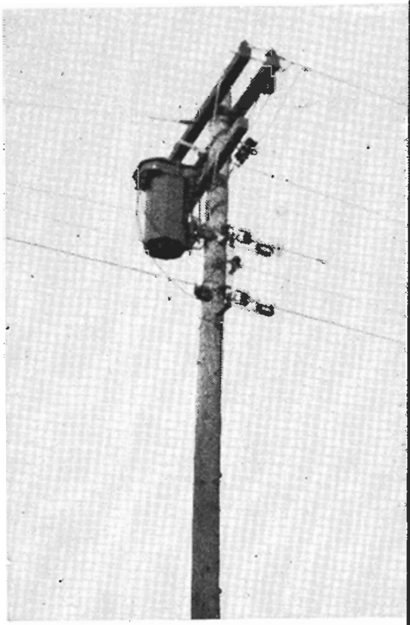


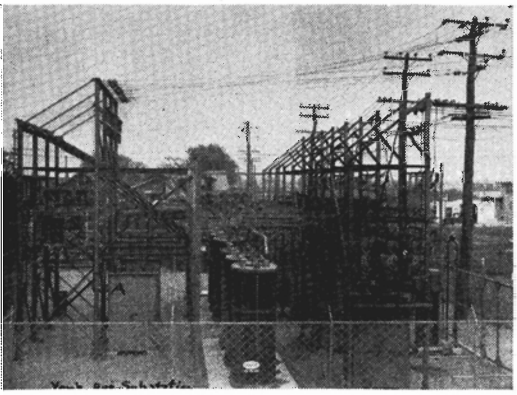


Reminiscent of the improvisation involved in early overhead construction practices is this picture of a 1914 pole moving operation supplied by the **SHERRARD POWER SYSTEM** of Orion, Ill. The model "T" will probably excite nostalgic memories of the many men still in the industry who helped pioneer system development.

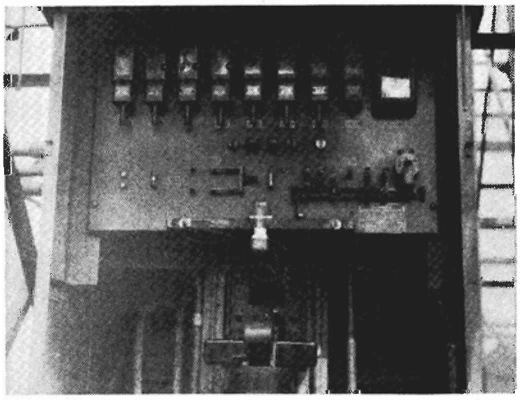
Where load densities could not justify underground service, engineers labored to improve the appearance, reliability and economy of overhead distribution. One of the earliest steps in this direction was the use of a common neutral ground wire for both the primary and secondary circuits. This saved one circuit in six and was used as early as 1915 by the **VIRGINIA ELECTRIC & POWER CO.** The two views shown below marked other overhead distribution improvements. At the left is the secondary rack installation which gave a far neater appearance to the structure. These extended secondary racks were developed by the **KANSAS GAS & ELECTRIC CO.** in collaboration with the telephone company to provide additional clearance between power and communication circuits. The economy of the joint use of poles for both power and communication is apparent, but many technical problems had to be worked out by power and telephone engineers before satisfactory communication could be obtained. Below right, banked secondaries on overhead systems provide better load distribution on transformers and more uniform customer voltage conditions. In case of faults, however, several transformers might be burned out before the fault is cleared. To avoid this difficulty, thermal switches have been used by some companies, the switches being inserted in the secondary circuits to open when excess currents flow. The installation shown is also on the system of the **KANSAS GAS & ELECTRIC CO.** which began banking transformer secondaries for improved customer service in 1937.



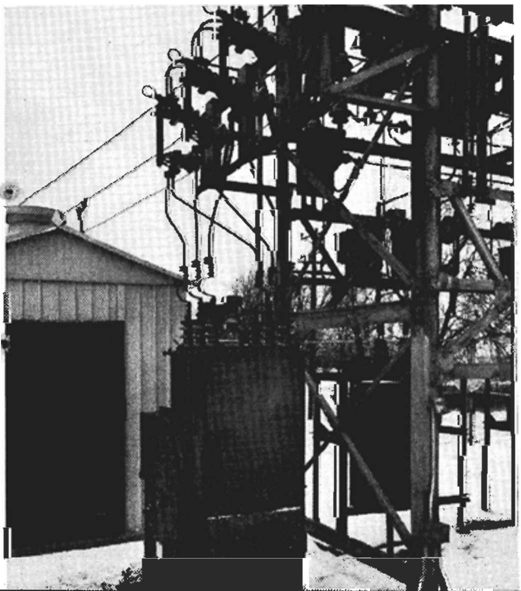


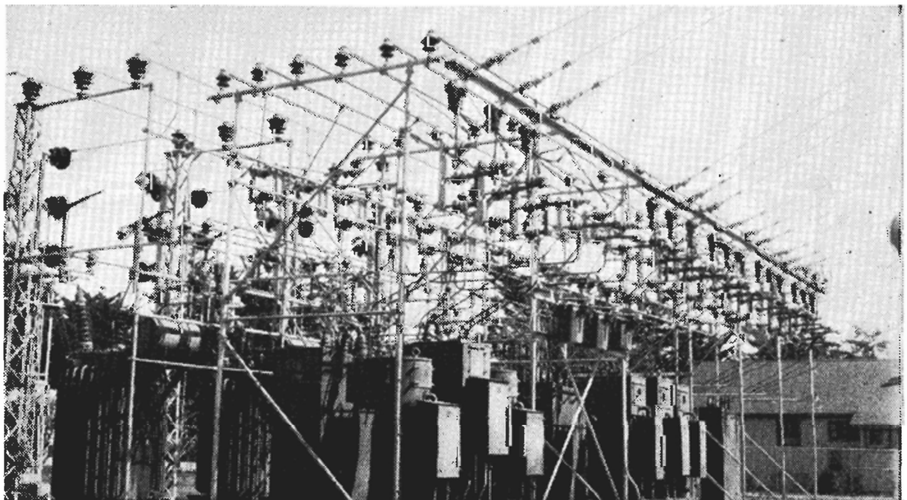


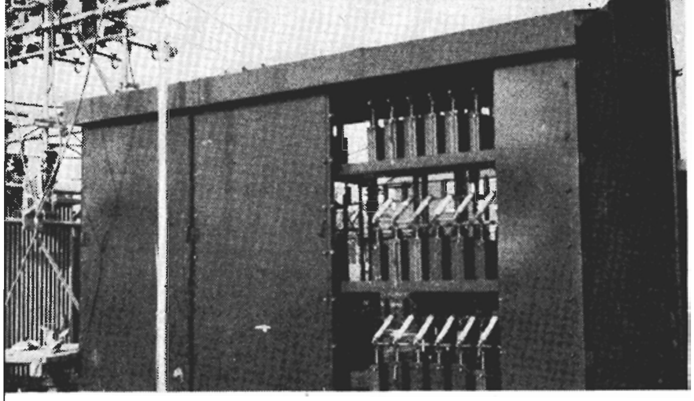
The **BLACKSTONE VALLEY GAS & ELECTRIC CO.**, in 1923, developed this unattended, fully automatic outdoor distribution substation. This station, shown in the view at the left, incorporated several unusual features, including automatic throw-over between preferred and emergency 13-kv feeders. Its four outgoing, 2,300-volt, distribution feeders were arranged for three automatic reclosers and a lockout on a permanent feeder vault. The view below shows a close-up of the original transfer relay equipment which was housed in the enclosure shown at the left center of the view above. Although the relay installation has been modernized, the substation continues in service today essentially as planned 25 years ago.



Voltage regulation on primary distribution circuits has been practiced since the early days of the industry through the use of automatic induction and the step-type regulators. The induction type regulator, because of its motor operated mechanism and relays, was essentially an indoor device. Later designers, by giving it a proper enclosure, enabled it to be placed out of doors with other substation equipment. Below is shown a 60-kv to 4-kv substation of the **PACIFIC GAS & ELECTRIC CO.**, installed in the late '20's with 4-kv outdoor type induction regulators controlling voltage on outgoing primary distribution circuits. At the left is shown an outdoor type, step-voltage regulator, built by the Allis-Chalmers Mfg. Co. and installed on the **OHIO EDISON CO.**'s system in 1933. This company pioneered step voltage regulation the previous year, installing the first unit sold by General Electric.

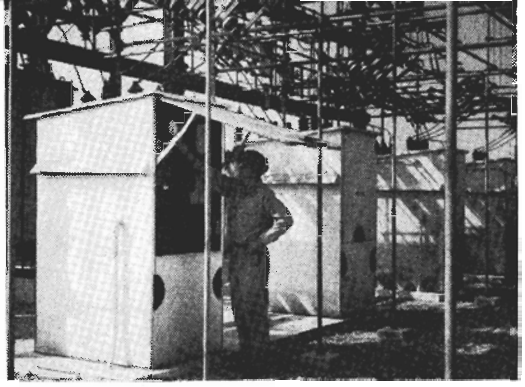


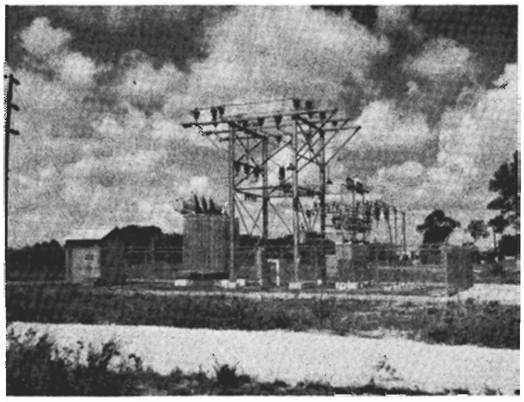


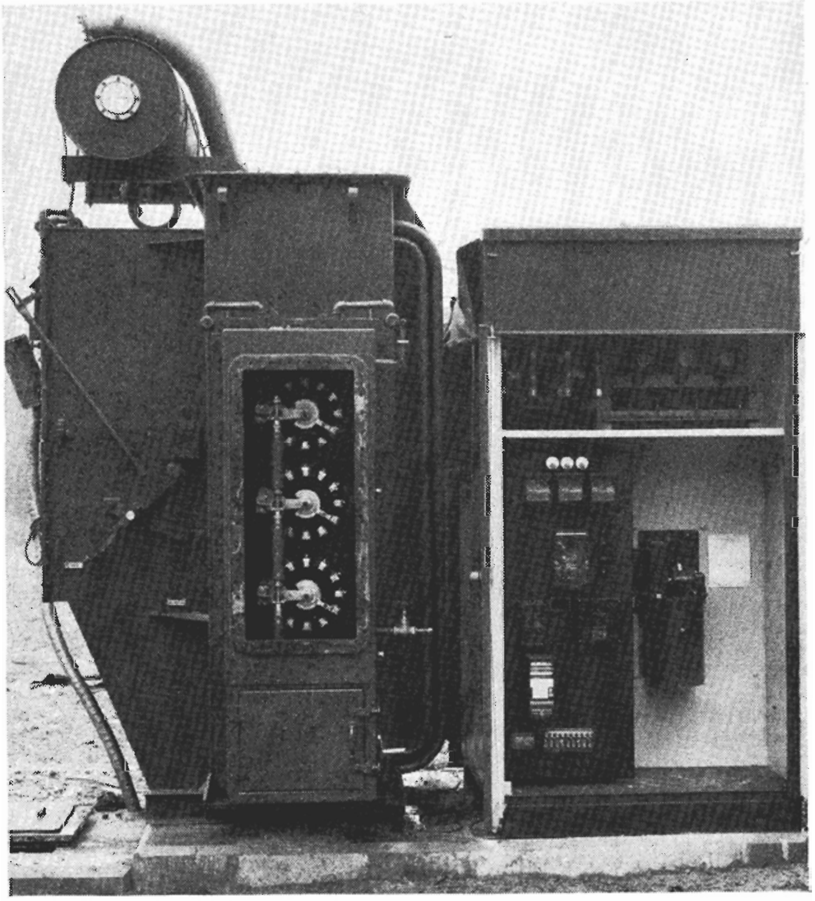


**THE PENNSYLVANIA POWER & LIGHT CO.** was among the leaders in the use of automatically-switched capacitors for circuit voltage control. The unit above was installed some time between 1928 and 1930. This company was also among the first to establish system voltage control in which the entire voltage level on both the transmission and distribution systems follows the load period, with consequent improvement in the performance of customer equipment served by this system.

Installations of reclosing breaker equipment for outdoor substations utilized indoor breakers installed in weatherproof housings as shown in this 1925 installation, right, on the system of the **FLORIDA POWER & LIGHT CO.** The modern version, right below, installed on the same system, features a 3-phase transformer and reclosing breakers built for outdoor service. Note the simplification of the substation structure.





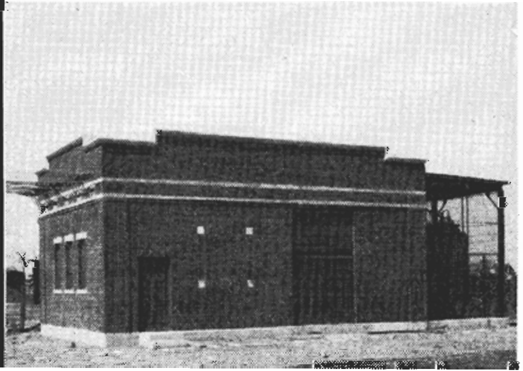


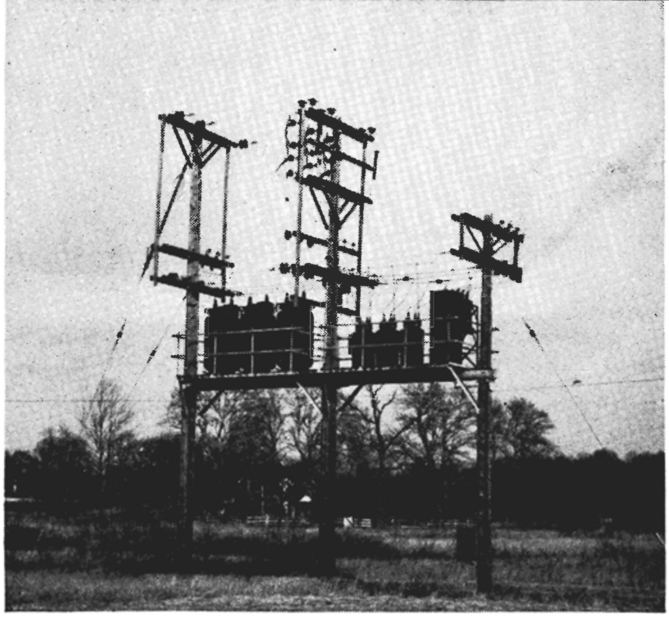
1931—Early use of unit substations for economical power distribution is exemplified by this installation on the system of the **CENTRAL HUDSON GAS & ELECTRIC CORP.** The basic advantages of unit substation construction, with its coordinated designs, saving in installation time and labor, plus high salvage value, marked a trend that has had a profound influence on substation designs since that date.

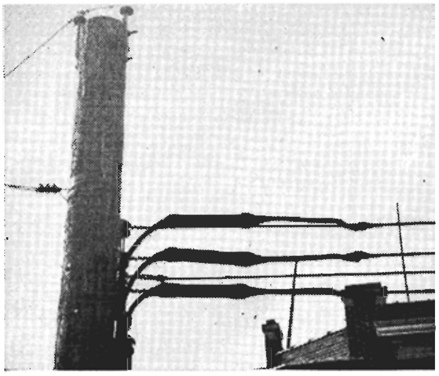
The above display is evidence of industry efforts to standardize ratings and mounting requirements for distribution transformers in the 1930's in the interest of simplification, and reduced manufacturing and installation costs. This is typical of displays at industry meetings throughout the nation. Much effort has been expended by manufacturers and power companies to attain economic benefits available through equipment standardization.

1926—Unit type of distribution substation (below) has been used in large numbers by the **BUFFALO NIAGARA ELECTRIC CORP.** Standardization has achieved maximum economy in engineering.

Typical of architectural treatment in substation design to harmonize with surrounding residential districts are these installations on the systems of the **KANSAS POWER & LIGHT CO.** and the **SAN DIEGO GAS & ELECTRIC CO.**, (right). By this means, the power companies have aided materially in beautification of residential areas and have contributed to good public relations.

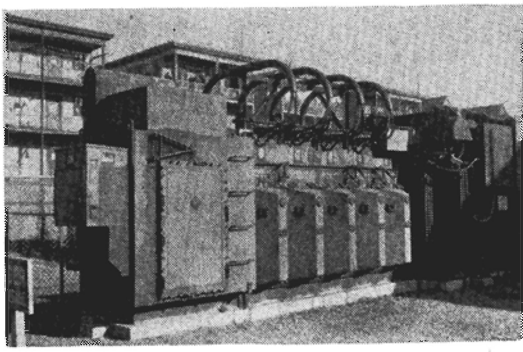




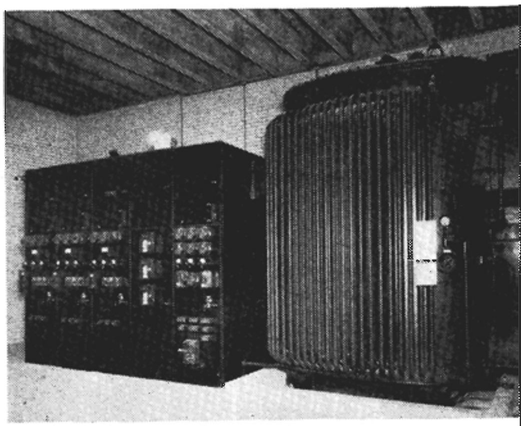


This 3-pole structure (above), with provision for three 33-kv transformers on one side and three voltage regulators on the other side, was first used by the **DELAWARE POWER & LIGHT CO.** on its radial distribution system in 1929. In 1941, several of these stations were converted to primary network operation by addition of the network oil circuit breaker on the right end of the structure. Left—network cable connection in the overhead secondary network of this same company. The enlarged section is a special unit developed in 1937, mounting a copper link network fuse. Conversion to the network distribution system gave customers a high degree of service performance.

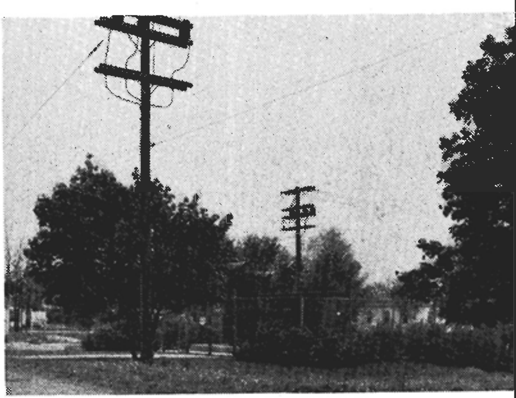
The 1500-kva unit substation, right, for primary network service on the **MALDEN ELECTRIC CO.** system was originally designed for submersible applications. Watertight housings, metal-clad interconnections and other submersible features contributed to exceptional ruggedness and dependability in outdoor service.

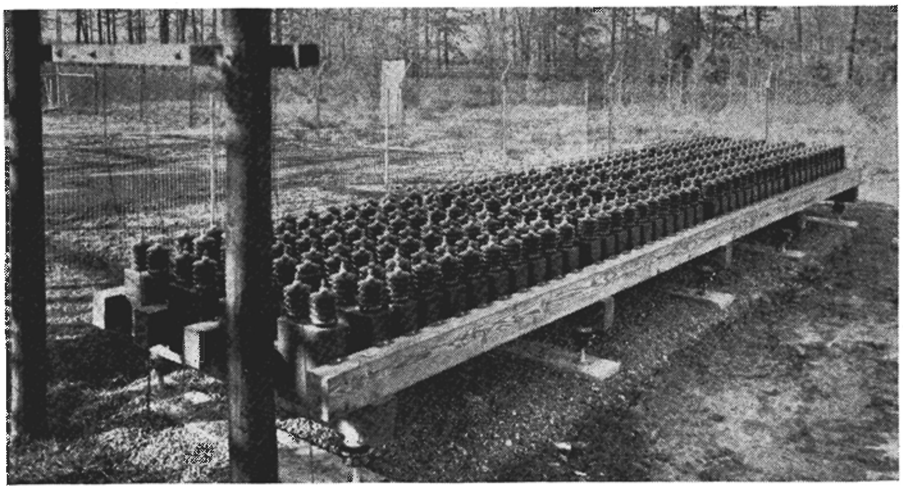


The indoor type of unit substation shown at the right is typified by this installation on the system of the **CAMBRIDGE ELECTRIC LIGHT & POWER CO.** The lower cost of the indoor unit substation equipment is somewhat offset by additional building costs, but other economies of the unit design are retained.



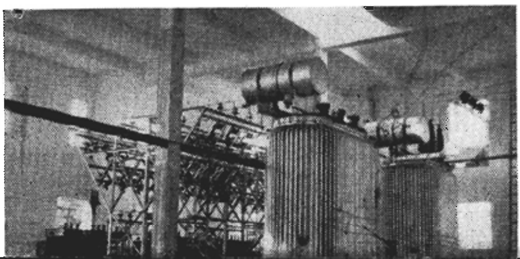
**THE INDIANAPOLIS POWER & LIGHT CO.**, also an early user of unit-type substation, will have 21 such units on this system by the end of 1947. The first unit, right, was installed in 1935 to provide for load increases in a growing residential section of Indianapolis.

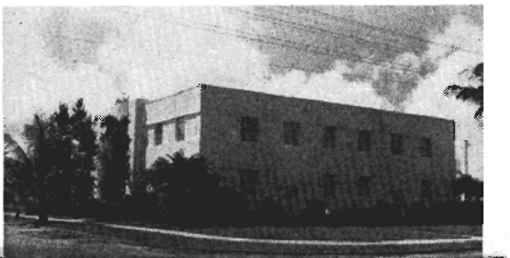




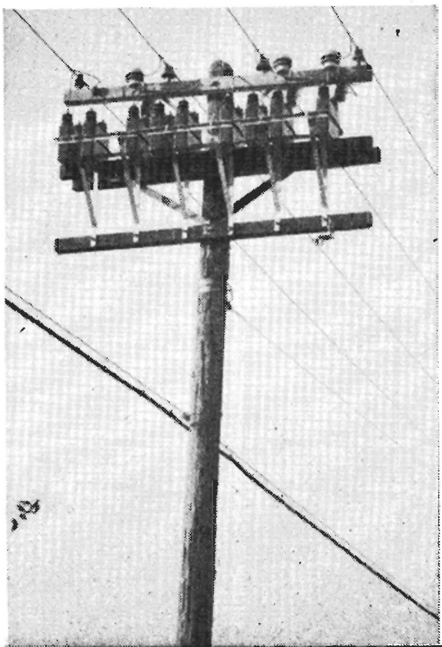
Calculator board studies made by the **ARKANSAS POWER & LIGHT CO.** during the war period showed that, for the estimated system loads, a major addition of reactive power supply would be necessary to maintain satisfactory voltage levels and loading conditions on lines and equipment. As a part of this program, the 2500-kva bank of capacitors shown above was installed in one of the company's substations. In order to conserve critical materials, these capacitor units were mounted outdoors on low insulated racks built of wood.

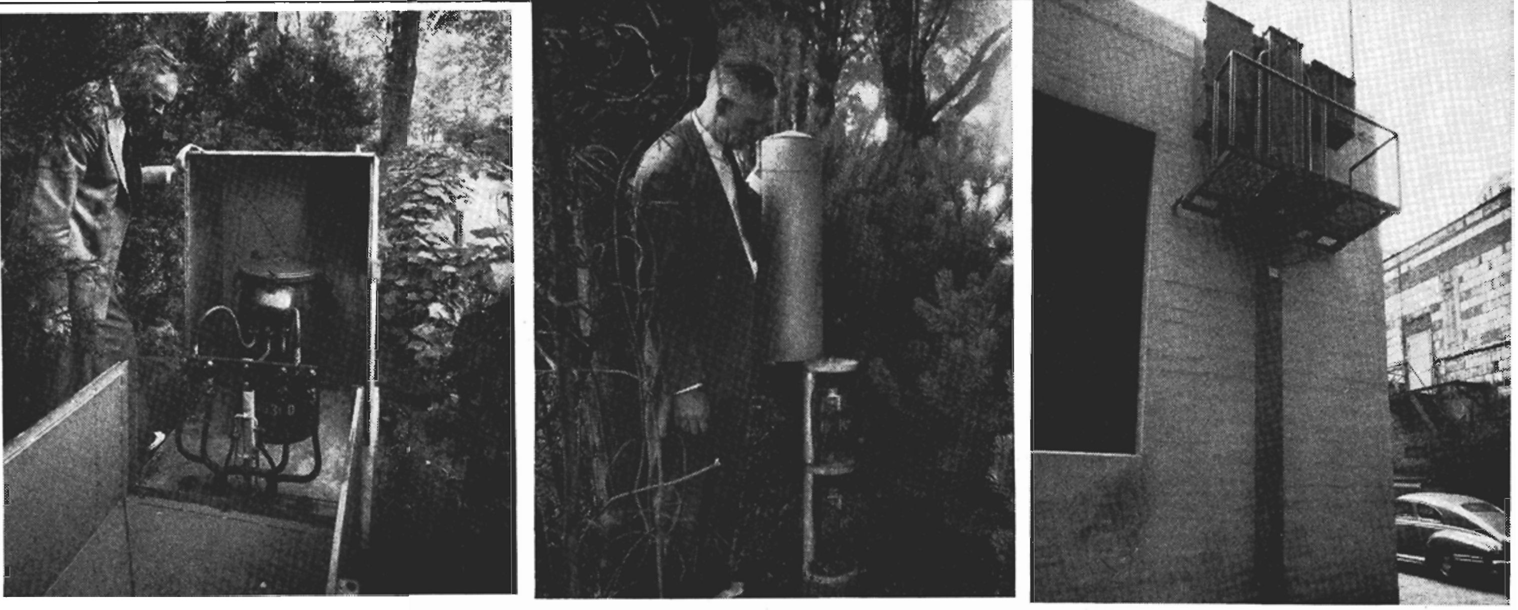
What appears to be a fashionable Miami Beach apartment house, below right, is actually a hollow shell housing the conventional outdoor substation equipment shown on the left. The **FLORIDA POWER & LIGHT CO.**, in using this method of camouflaging equipment, invested in customer goodwill and contributed to civic improvement.



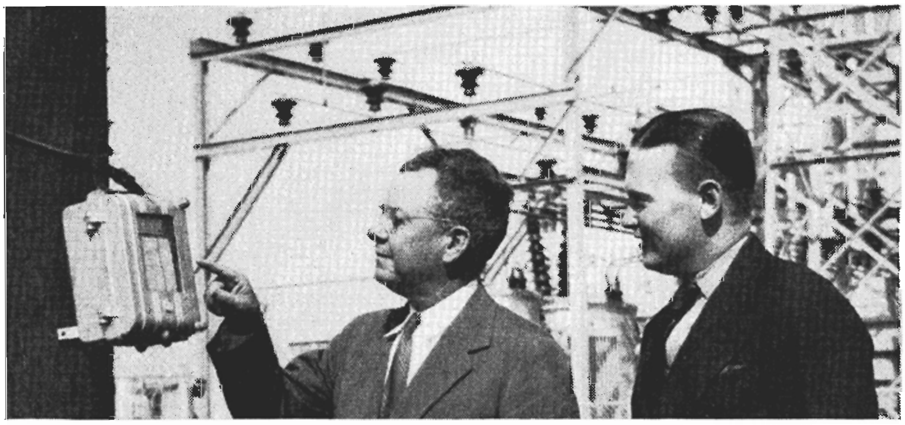


The pole-top capacitor installation below, on the system of the **OKLAHOMA GAS & ELECTRIC CO.** is typical of installations on urban type feeders for heavy load densities. Capacitors effect a reduction not only of voltage drop, but also ampere demand, and energy losses. Power company engineers have made steadily increasing use of capacitors to improve distribution efficiency and economy.

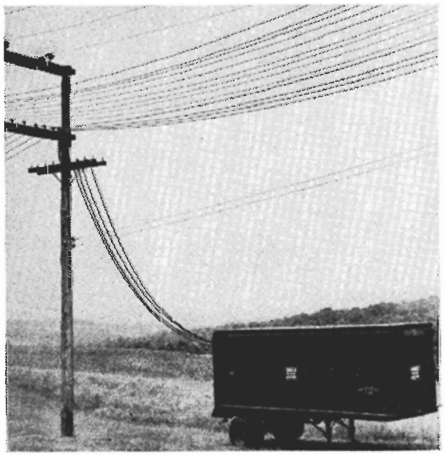




The **DETROIT EDISON CO.** is one of several companies which developed low-cost underground distribution facilities for highly restricted residential areas. Poles were eliminated by burying the conductors. Transformers were installed above ground and housed as shown at the left above. Secondary mains and services are conected to two buses located one above the other in the inside of the pedestal shown at the center above. Standard underground construction costs were reduced considerably by this type of installation, which made it unnecessary to build manholes or to provide submersible equipment. Above, right—the steel-column-mounted 150-kva transformer, with throat-connected network protector and disconnect box, installed in an alley, is a part of a low-cost a-c secondary network of that company. This development represented an economical type of network service which enabled the company to meet increasing demands for a-c service in a district previously served with d-c only.



1939—50 portable recording voltmeters were used by the **CENTRAL POWER & LIGHT CO.** in a voltage correction field study. Rapid system growth was responsible for the low voltage conditions disclosed by the study. Remedial measures adopted included changing transformer taps, balancing and transferring loads, closing secondary loops, installing additional transformers and regulators, and reinforcing the primary system. Improved service, increased consumption and revenue resulted from the program. Continuing studies of a similar nature are a necessity on the modern power system in order to ensure the high quality of service enjoyed today.



Shown above is an outdoor mobile capacitor unit in service at a rural substation of the **CONSOLIDATED GAS ELECTRIC LIGHT & POWER CO. OF BALTIMORE** to meet the emergency demands of an industrial customer. Units of this type enable utilities to serve loads characterized by low power factor and extreme current peaks until such time as adequate permanent facilities can be provided.

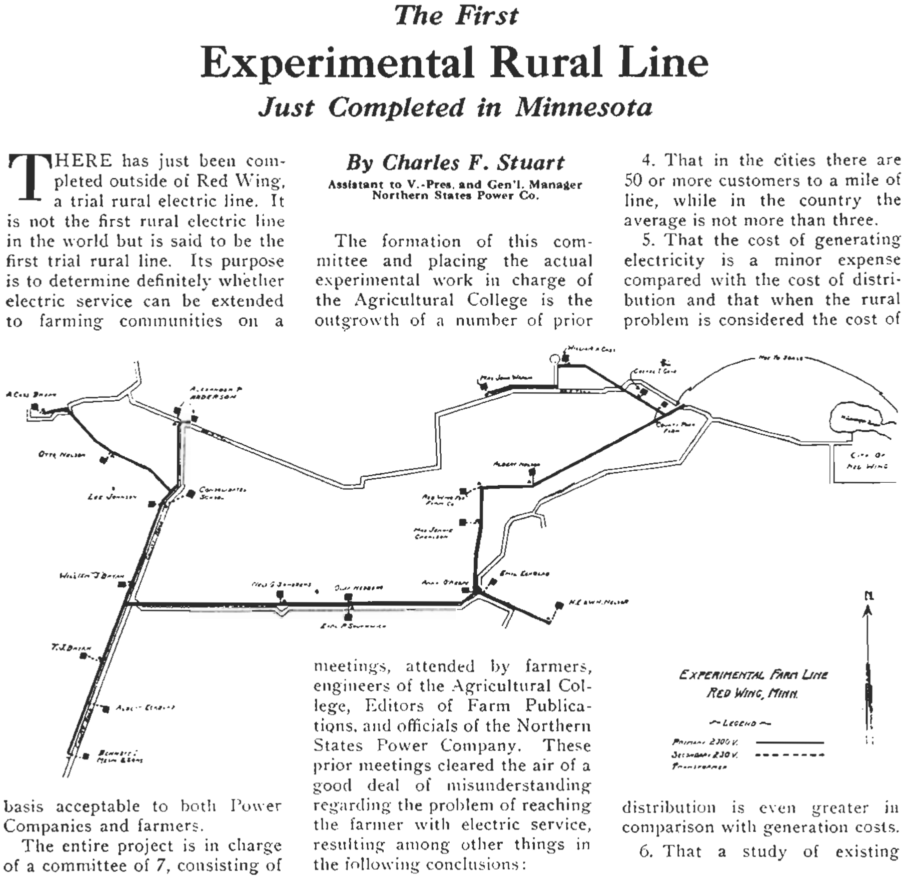
The tower and ladder trucks shown in the two views below, as used for street and highway lighting construction and maintenance, are indicative of the special facilities developed by the industry to improve the efficiency of such operations. Savings thus effected have materially contributed to the maintenance and betterment of street and highway illumination.

**1909—The oldest farm electric customer the editors could locate. Rural electrification by the PACIFIC POWER & LIGHT CO. was born here near Hood River, Ore. The line built to serve this and other farms in the area was an early part of a progressive and continuing rural expansion program carried on by power companies many years prior to the formation of REA. In pioneering farm electrification, the companies not only had to build facilities, but also to follow through with campaigns to develop suitable farm utilization equipment and to sell the farmers on using it.**

FARSIGHTED electric companies recognized from the very start that anything done to improve rural standards of living, and to help the farmer increase his production and income, would benefit the city dweller and the region as a whole. The power companies first had to solve the problem of bringing the cost of rural electric service within the economic reach of prospective farm users. Then it was necessary to determine the type of equipment the farmer needed; to develop, test and prove its economic feasibility; and finally, to acquaint the farmer with the equipment and its advantages.

Establishment of the National Committee on the Relation of Electricity to Agriculture, in 1923, was the most important step toward solving these problems. State committees, fostered by this parent organization, consist of representatives of the agricultural colleges, leading farmers, equipment manufacturers and power companies. Most power companies maintain an organization of farm specialists, trained in agriculture and the adaption of electricity to farm use.

By the end of 1948, through the combined efforts of the power companies, electric co-operatives, and other public agencies, electric service will be available to all but the most inaccessible occupied farms in the United States.



*The First*

# Experimental Rural Line

*Just Completed in Minnesota*

***By Charles F. Stuart***

**Assistant to V.-Pres. and Gen'l. Manager**
**Northern States Power Co.**

THERE has just been completed outside of Red Wing, a trial rural electric line. It is not the first rural electric line in the world but is said to be the first trial rural line. Its purpose is to determine definitely whether electric service can be extended to farming communities on a basis acceptable to both Power Companies and farmers.

The entire project is in charge of a committee of 7, consisting of

The formation of this committee and placing the actual experimental work in charge of the Agricultural College is the outgrowth of a number of prior meetings, attended by farmers, engineers of the Agricultural College, Editors of Farm Publications, and officials of the Northern States Power Company. These prior meetings cleared the air of a good deal of misunderstanding regarding the problem of reaching the farmer with electric service, resulting among other things in the following conclusions:

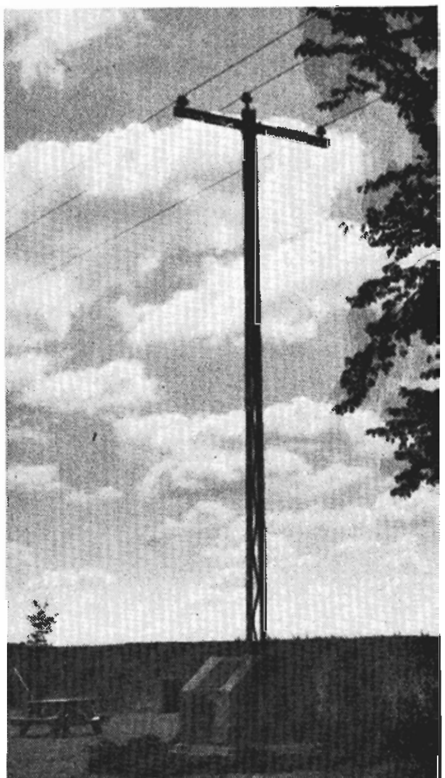
4. That in the cities there are 50 or more customers to a mile of line, while in the country the average is not more than three.

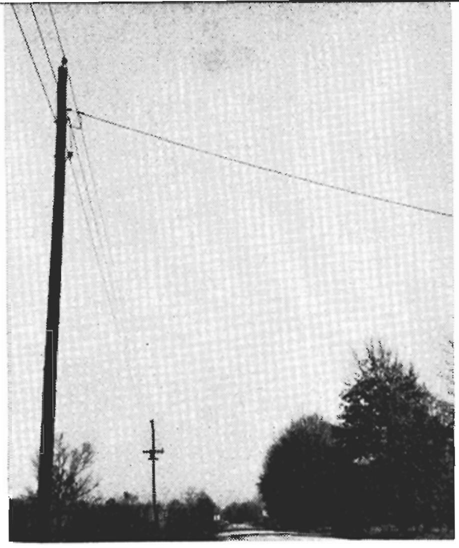
5. That the cost of generating electricity is a minor expense compared with the cost of distribution and that when the rural problem is considered the cost of distribution is even greater in comparison with generation costs.

6. That a study of existing

**Reproduced above is a portion of a feature article published in the January, 1924 issued of ELECTRIC LIGHT and POWER. Construction of this trial line was significant in that it was an early example of cooperative development work conducted jointly by the state College of Agriculture and the power company. Cooperative efforts of like nature throughout the country in subsequent years have contributed in large measure to the wide-spread farm electrification thus far accomplished.**

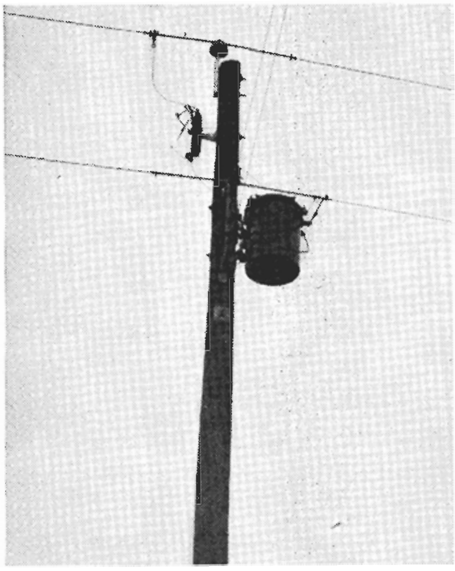
**CONSUMERS POWER CO. constructed its first line for the specific objective of rendering farm service in 1925. The following year, the Michigan State College requested the company to build a rural line near the college to permit joint study of the economical and sociological effect of farm electrification. The monument, below, in a Michigan State Highway park forms a part of that experimental electrification line. To secure service, the farmers had but to wire their buildings, and yet only 13 of the 33 farmers along the route were sufficiently interested to take advantage of the opportunity, indicative of the selling job that had to be done to interest rural customers in the benefits of electricity.**





**Radical measures to make farm lines justifiable economically had to be devised by power company engineers if wide-spread electrical service was to be brought to the farms of the U.S. Low cost line design took the form of long-span construction, utilizing high strength conductors without cross-arms, which reduced the number of poles required from about 40 to 15 per mile.**

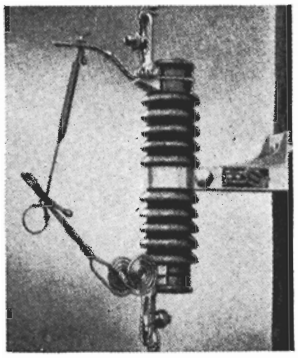
**This long-span, rural line construction of the TEXAS ELECTRIC SERVICE CO., shows, in the rear, a transformer pole with the secondary carried to the pole in the foreground. The pinnacle pin support for the primary, the common neutral center wire and the single secondary wire carried on the lower bracket provide the most economical construction for circuits having three to five customers per mile. Note the method of attaching secondary customer drop leading across the road.**

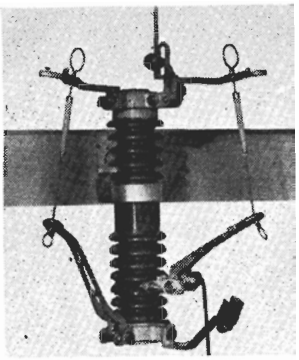


**Detail of a transformer pole on the KANSAS GAS & ELECTRIC CO.'s system showing mounting arrangement of equipment for maximum economy. Note the fuse protection, the use of the common neutral for primary and secondary circuits and the method of mounting all equipment with through-bolts, eliminating cross-arm and hanger expense.**

**Details of the low cost protective equipment which has found wide application on rural lines. The two views at the right show a single link primary fuse and the "two-shot" cutout.**

*Photos courtesy of J. R. Kearney Corp.; W. N. Matthews Corp.; Schweitzer and Conrad Co.; and Pacific Electric Mfg. Co.*





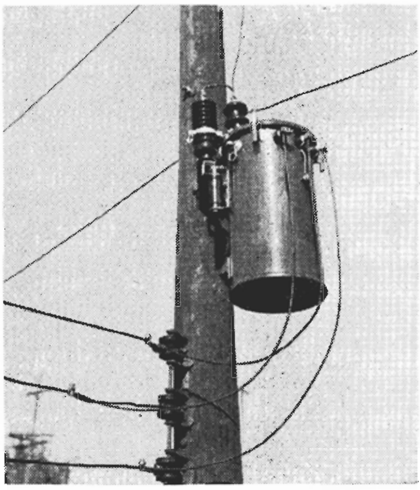
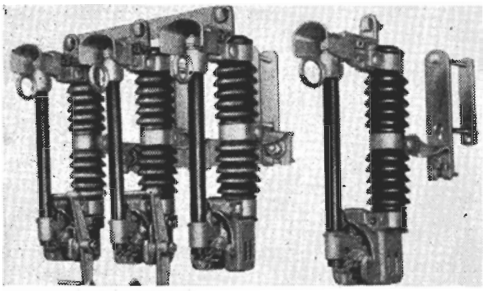
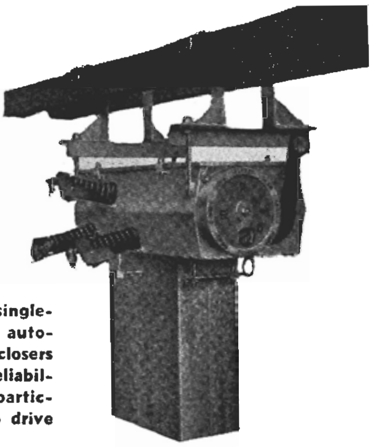


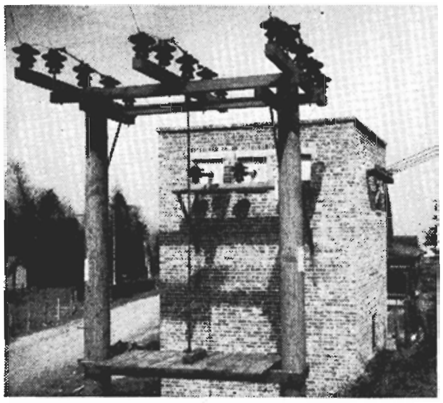
*Photo courtesy of Westinghouse Electric Corp.*

**1933 — Pioneering efforts to achieve "built-in" protection for both the equipment and the service resulted in development of the completely self-protecting type of distribution transformer shown above. "Lightning-proof", this coordinated unit design maintains service to the consumer during high short-time overloads, gives warning if dangerous temperatures are approached, and trips clear on long-sustained overloads or secondary faults.**

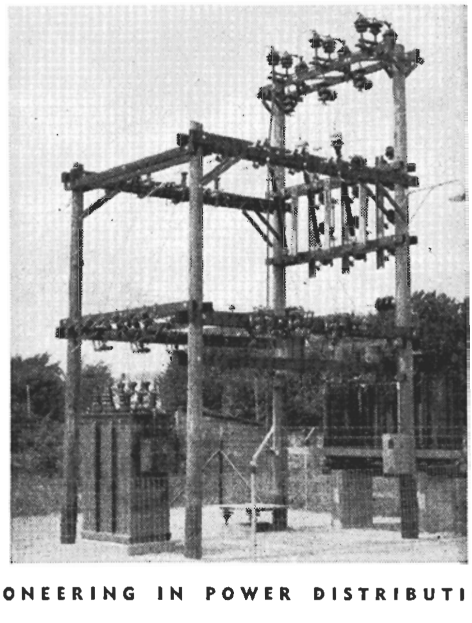




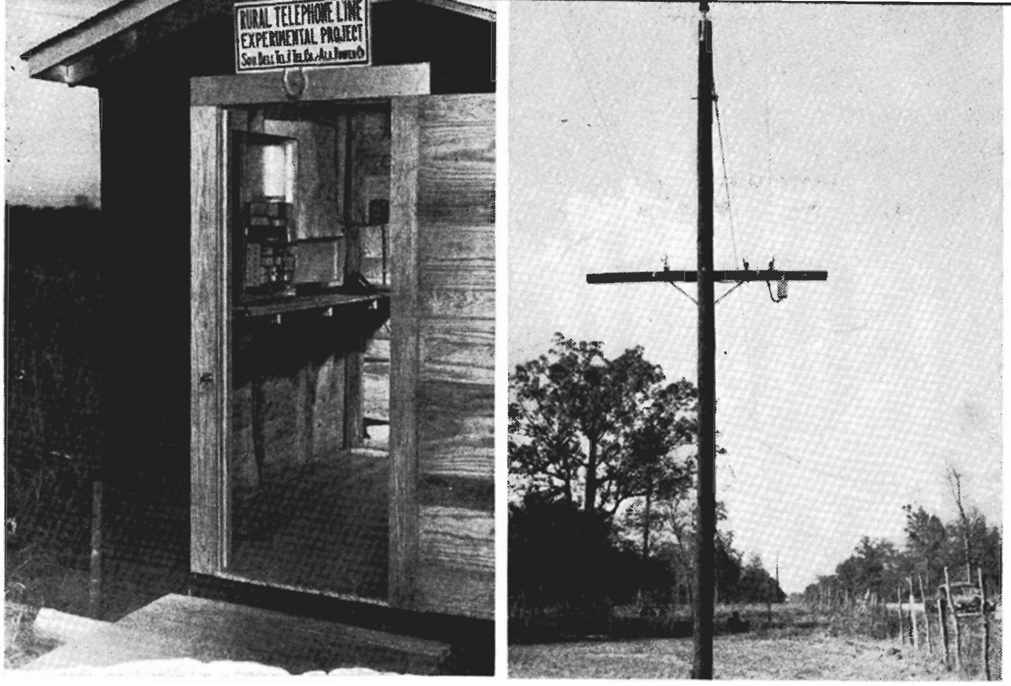
**Above, a drop-out type "three-shot" reclosure with a "single-shot" unit immediately adjacent. Right, an inexpensive, automatic type of oil circuit breaker which provides three reclosers before lock-out. These four devices provide much higher reliability of service and reduce outage time and loss of revenue, particularly in the more remote areas where servicemen have to drive considerable distances.**



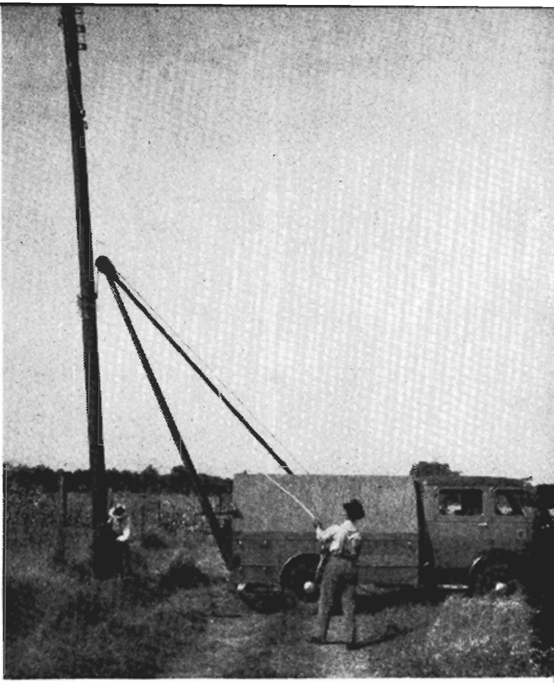
**When the PUGET SOUND POWER & LIGHT CO. constructed this rural substation, in the early 1900's, only indoor type substation equipment was available. It, therefore, was necessary for the company to construct the enclosure on the job, a high-cost procedure when compared with the modern outdoor units which can be placed in service with a minimum of field labor and expense.**



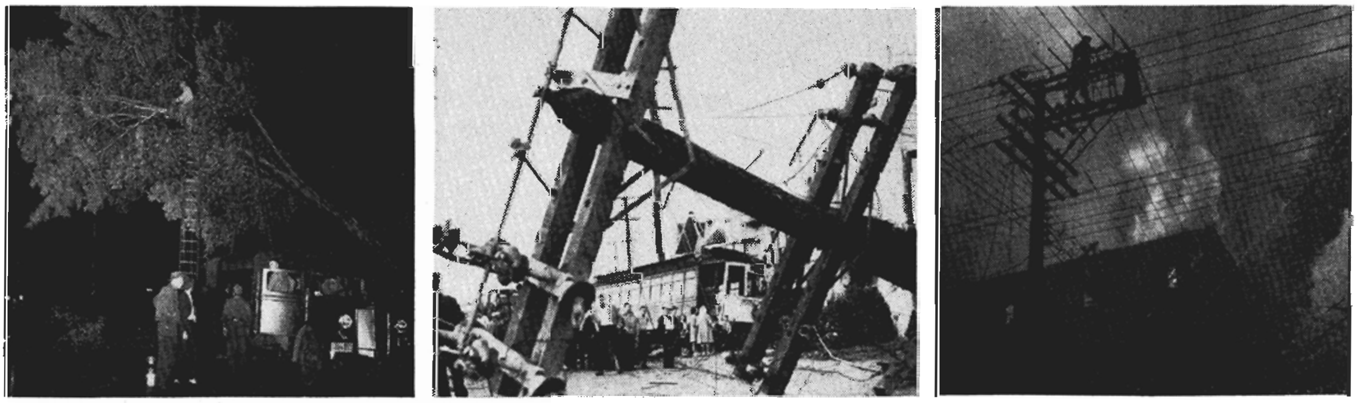
**Left, excellent example of a rural distribution substation, by the WISCONSIN POWER & LIGHT CO., which pioneered rural electrification in the rich Wisconsin dairyland area. On the wood pole structure are mounted the high-voltage disconnects and high-voltage fuses to protect the transformer banks shown at the extreme right. Lightning arresters may be seen on the upper rear cross support, which also serves as the take-off for rural primary feeders. On the lower cross support are mounted reclosing fuses. The design packs maximum reliability and protection to both equipment and service into a structure of great economy of investment.**



Since the war power companies have been working jointly with the American Telephone & Telegraph Co. to provide telephone communication over power company circuits by means of carrier current. Successful installations have already been completed, such as the one above on the **ALABAMA POWER CO.**'s rural circuits. The power and telephone industries have many interests in common, both serving essentially the same customers and both using pole line construction for their circuits. By avoiding duplications of materials and construction, engineers believe that telephone service could be extended much more rapidly to a quarter of a million customers now located beyond existing telephone lines but who are served with electricity by the power companies. While this study is still in the developmental stage and while equipment is complicated, the pioneering work already accomplished shows great promise for rendering more expansive utility service to the farmers at minimum costs.

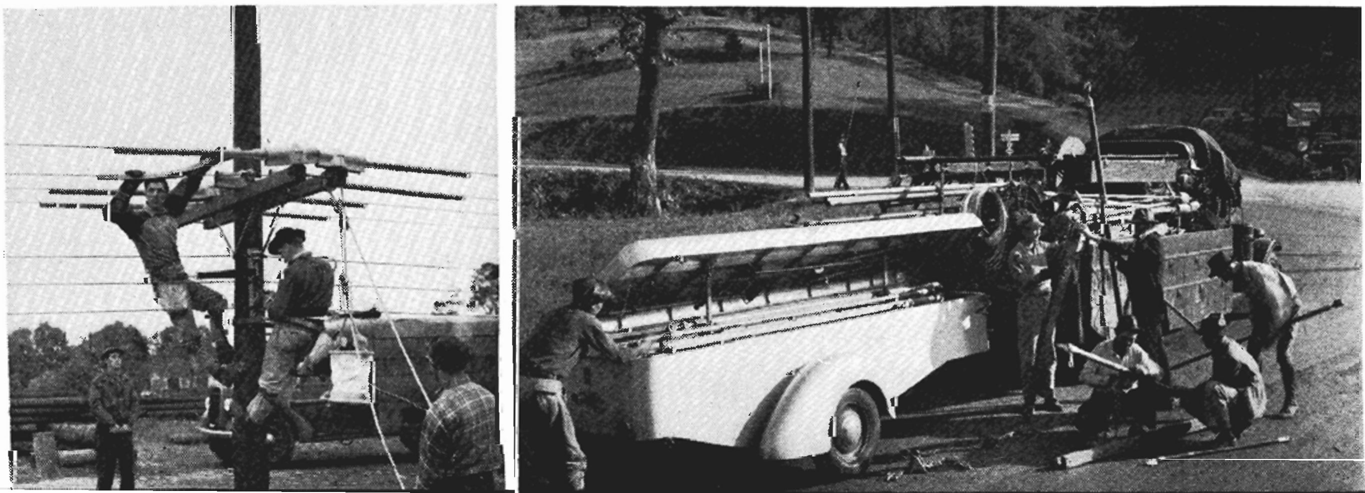


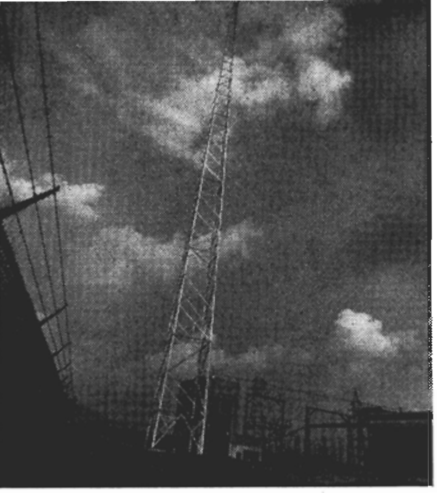
Modern rural line truck of the **OKLAHOMA GAS & ELECTRIC CO.** enables poles to be set with minimum time and effort. Note the six man cab on the truck which provides seating space for the members of the crew behind the driver, a development which greatly improved the comfort and safety of the crew while on the move.



**EMERGENCY SERVICE.** Wind storms, accidents, fire, sleet, low-flying airplanes and a variety of other phenomena concomitant with modern civilization result in damage to or trouble on power company lines, structures and facilities. To meet the demands for speedy restoration of service and to minimize the hazards involved in displaced or broken circuits, power companies have developed highly organized, well equipped trouble crews which are on call day and night. This emergency program is inter-system in its scope. For example, power companies within their various organizations have arranged well planned disaster procedures in case of wide-spread damage such as may be done by tornado or flood. Under such circumstances trouble crews from one system move into the stricken area to render emergency service, get essential facilities functioning again, often providing humanitarian relief beyond the immediate electrical reconstruction work involved.

Well-trained and highly skilled technicians, plus modern, specialized tools and equipment, are the secrets of the power companies' ability to deal with troubles and emergencies quickly and efficiently. Below left, line crews are taught how to work safely on low pole structures. Below right, the crew with this line truck and special trailer for "hot line" tools prepares for action.





**Short wave radio communication between the dispatcher's office and mobile units in the emergency, construction and service fleets of the power company minimize outage time and customer inconvenience. Above is shown the transmitting tower of the two-way radio communication set up for the DUQUESNE LIGHT CO.**

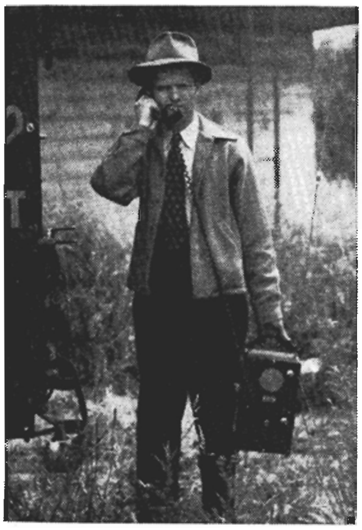
**The KANSAS CITY POWER & LIGHT CO.'s dispatcher, above, is transmitting information to trouble crews in the field, through the medium of this company's extensive FM radio communication network. This system insures a minimum of lost time in handling emergencies, plus maximum efficiency in all routine operations.**

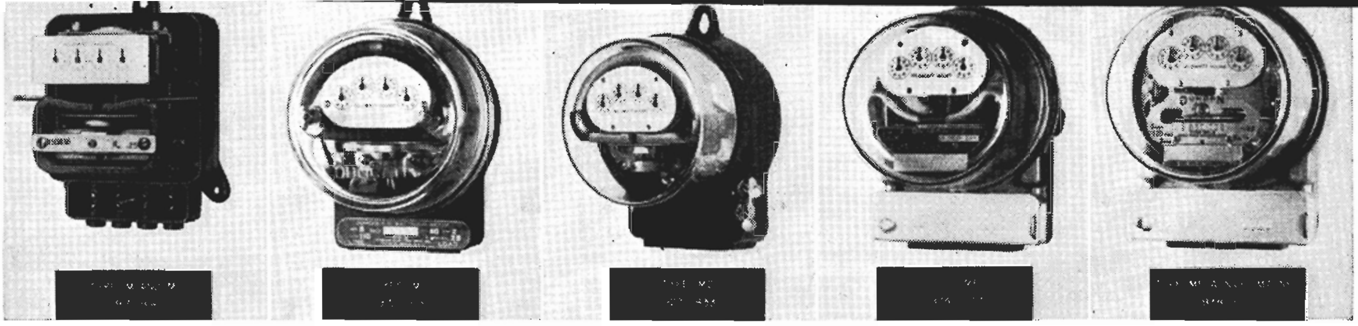
**This car is one of over 50 service vehicles on the system of the UNION ELECTRIC CO. OF MISSOURI, which are equipped with two-way FM radio communication equipment. Control unit and microphone hand-set are mounted on dashboard. Immediate contact with communication headquarters is invaluable in handling trouble or service calls and a good builder of customer appreciation and good will.**

**The radio-telephone in the line truck below is being used here by the line foreman to handle clearances and request materials, thus enabling the crew to function at maximum efficiency.**

Communication became indispensable to power system operation with the establishment of the first dispatching centers. Commercial telephone service, supplemented by company-owned telephone systems, sufficed for a number of years. Still later, carrier current type communication equipment was utilized to provide communication between major stations interconnected by transmission lines, which served as the carrier channel. More recently, very extensive use has been made of two-way radio-telephone equipment, which has the important advantage of providing contact with line construction and trouble crews in trucks equipped with mobile units. The AM sets first used have been replaced in large measure by FM sets, which are essentially free from electrical disturbances. Operating efficiency and service continuity have been materially improved, and the handling of trouble and emergency calls has been facilitated by the use of two-way radio-telephone equipment.

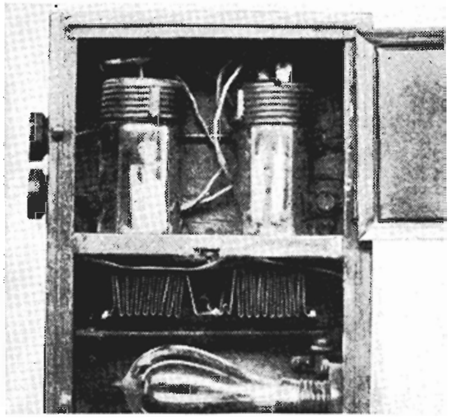
**The NORTHWESTERN ELECTRIC CO., a pioneer company in radio operations, carries modern short wave communications one step farther by using "walkie-talkies" for point-to-point service. Portable equipment of this type has proven to be most helpful during line construction, submarine cable maintenance and similar operations when trucks or cars cannot be brought to the scene of activity.**





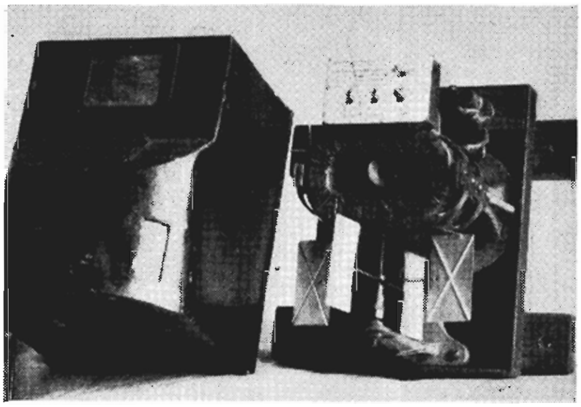
*Photos courtesy Duncan Meter Co.*

**Evolution of the house-type watthour meter, since 1913, is typified in the series of pictures above. Design improvements incorporated in these meters have brought about a steady increase in accuracy and reliability, due to better mechanical and electrical design. Introduction of accurate compensation for temperature changes, elimination of no-load "creep", accurate registration at extreme light loads, and the like, have given the watthour meter the attributes, at a fraction of the cost, of a fine watch. High-grade manufacturing technique, coupled with quantity production, has made possible this accurate, dependable "cash register" of the power industry.**



**The first commercially satisfactory electric meter used for billing customers for current was the Edison chemical meter shown above. It was installed on the lines of the CONSOLIDATED EDISON COMPANY'S predecessor in New York in 1882. Computation of current flow was made by tedious checking of the relative weight of the material in the two jars at stated intervals—a far cry from the modern meter with direct dial indication.**

**When the alternating current system was launched, in 1885, the problem of measuring the customer's energy bill was unsolved. Even direct current service could be measured only very clumsily and expensively. Invented in 1888 by Shallenberger, a young Westinghouse engineer, the induction type ampere-hour meter on the right became the first a-c integrating meter; the parent of all a-c watthour meters now in use.**



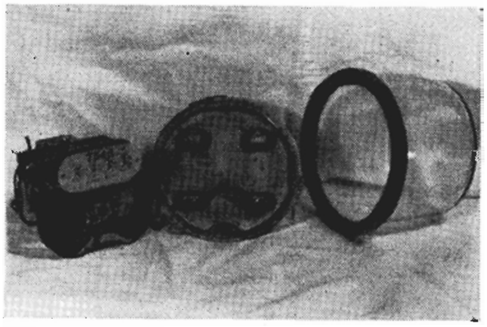
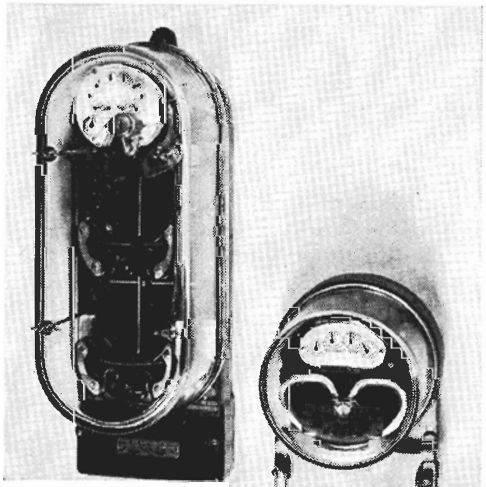


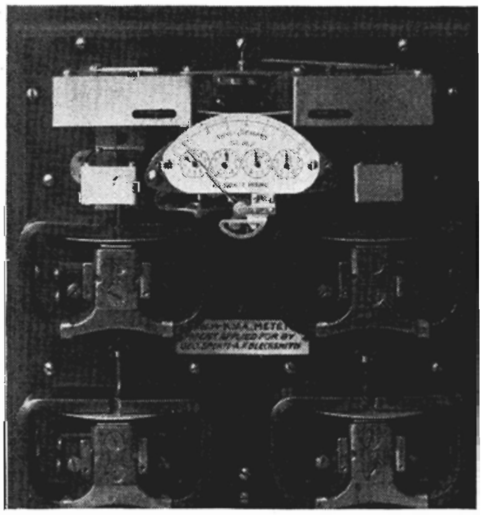
*Photo courtesy Sangamo Electric Co.*

**In the absence of the home owner, power company meter readers were unable to obtain a reading when house meters were installed indoors. Resultant "skip" readings were a source of customer complaints. Changeover to outdoor metering in the early '30's eliminated this difficulty. The OHIO PUBLIC SERVICE CO. was a pioneer in this field. Indoor meters already on hand were adapted to outdoor service by means of the special base and cover shown on the left.**

# *Meter Developments*

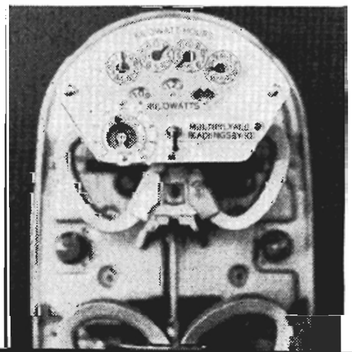


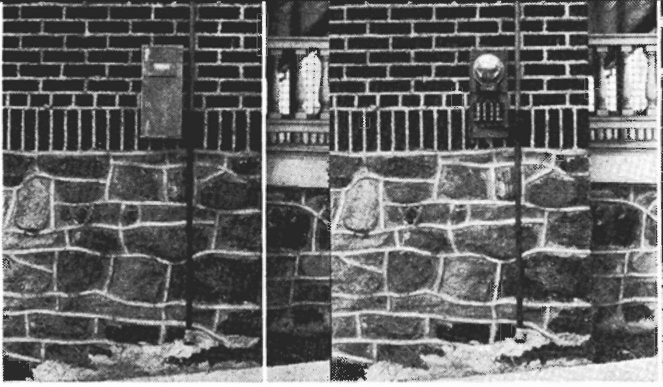
**Design progress by watthour meter manufacturers, in decreasing meter size and complexity and increasing accuracy and reliability, is typified in the above comparison of the old (left) and new (right) three-element polyphase watthour meters.**



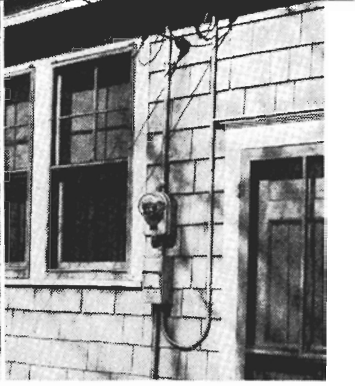
**1921 — To meet the need for an integrating kwhr and kva-demand meter for billing large industrial customers, two employees of the electric meter department of the CINCINNATI GAS AND ELECTRIC CO. developed the meter shown above. Patent rights were purchased by the Westinghouse Electric Corp. The development led to wide-spread use of the kvahr and kva-demand meter, which brought the customer the benefits of metering more scientifically tailored to fit his power demands.**

**Watthour meters which registered cumulative demand, first used in 1916, left no record of the demand value after the sweephand was returned to zero by the meter reader. In 1934, the PHILADELPHIA ELECTRIC CO. originated the design on the right, in which the sweephand, during reset to zero, operates a set of dials that record the added amount of the demand and gives a numerical reading like the watthour dials.**



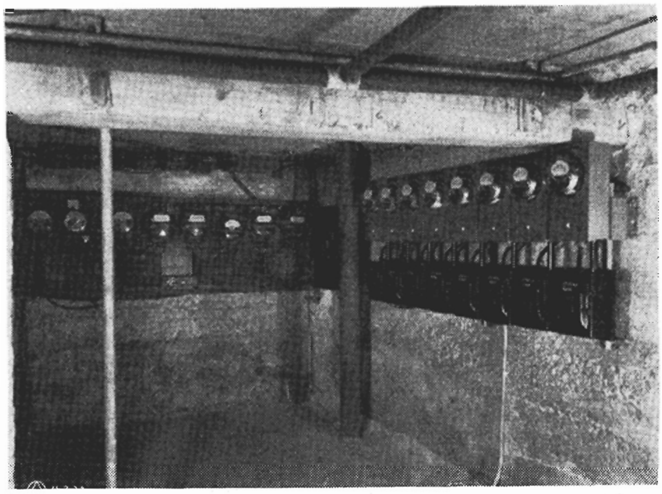


1928—An important contribution to the bettering of public relations was made by the electrical industry with the development and use of outdoor metering equipment, which made the house meter readily accessible for the periodic visits of the meter reader. The **METROPOLITAN EDISON CO.** aided materially in the rapid advancement of outdoor metering when it designed and introduced the first metal outdoor meter box. Illustrations above show a 1928 installation of a meter and meter box on the exterior of a typical residence, with and without the outer box covering.



A serious bottleneck in utility promotion of electric range installations was the high cost of running in special services for these ranges. A number of years ago, the **KANSAS GAS AND ELECTRIC CO.** overcame this handicap by developing the cast aluminum box, equipped with thermal type switches, installed below the socket type meter (left). This set up provided separate service to the range at a cost considerably less than any previous method.

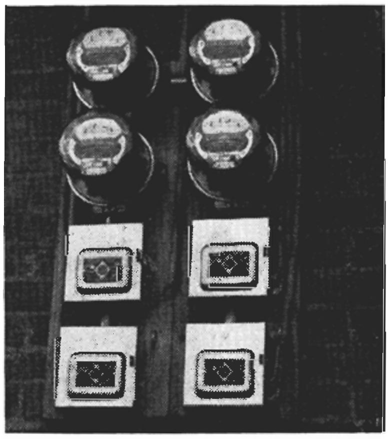
The watthour meter installation and service truck above is typical of those used by power companies throughout the country for periodic replacement of residential type meters. Meters removed from service are replaced with new meters or meters which have been reconditioned, accurately checked and calibrated at the company's meter service center. This periodic replacement service ensures accurate registration of household power use and assures that no customer will be overcharged for the power consumed.

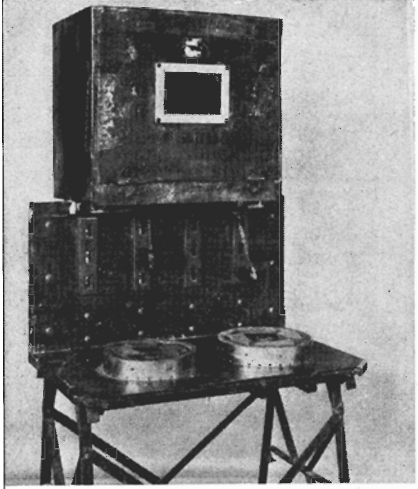


Large apartment buildings require centralized metering facilities such as shown above. Note the old style facilities on the left, with exposed meter wiring, offering opportunity for tampering. The bank of meters on the right, more recently installed, features enclosed wiring throughout, a safeguard to customer service.

Extensive facilities and a large force of highly trained test men are provided by the power companies to maintain a constant check on the accuracy of the watthour meters which register power consumption in the home. The **FLORIDA POWER AND LIGHT CO.** meter test crew, left, is conducting calibration tests on house meters.

Outdoor socket type watthour meters provide neat and compact metering facilities for multi-family flats and small apartment buildings. Typical facilities for a four-family flat are shown below. This set up effects maximum economy in meter reading, avoids disturbance to the householders, and eliminates "skip" readings.



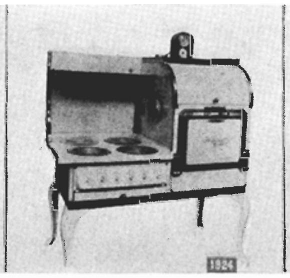


**Evolution of the electric range from 1905 (extreme left) to 1941, is depicted in the series of pictures to the left and below. Lack of commercial development of electric cooking prior to 1905 was ascribed to the lack of daytime service by central stations outside of the large cities. Early electric cooking power rates were from five to ten cents per kwhr, and range designers hesitated to speed up the heating elements, by putting more power in them, because of frequent burnouts. Shown directly on the left is a range developed by George A. Hughes in 1910, which is considered to be the forerunner of the present electric range business. It was made out of a gasoline range frame, in which electric elements and switches had been mounted and the oven of which had been insulated. Nickel chromium wire was used in the heating elements. The first carload of these ranges was ordered by the MONTANA POWER CO. Range developments throughout the years have brought modern temperature controls, insulated ovens, timers, closed coil units, and other refinements. At present cooking rates, the cost of the power consumed by the million electric ranges now in use averages about one cent per person per meal.**

*Photos courtesy Hotpoint, Inc., and General Electric Co.*

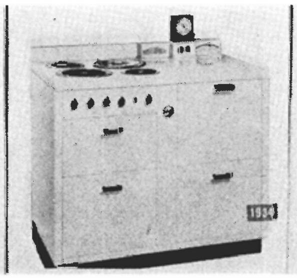
1917

1919



1924

1927



1934

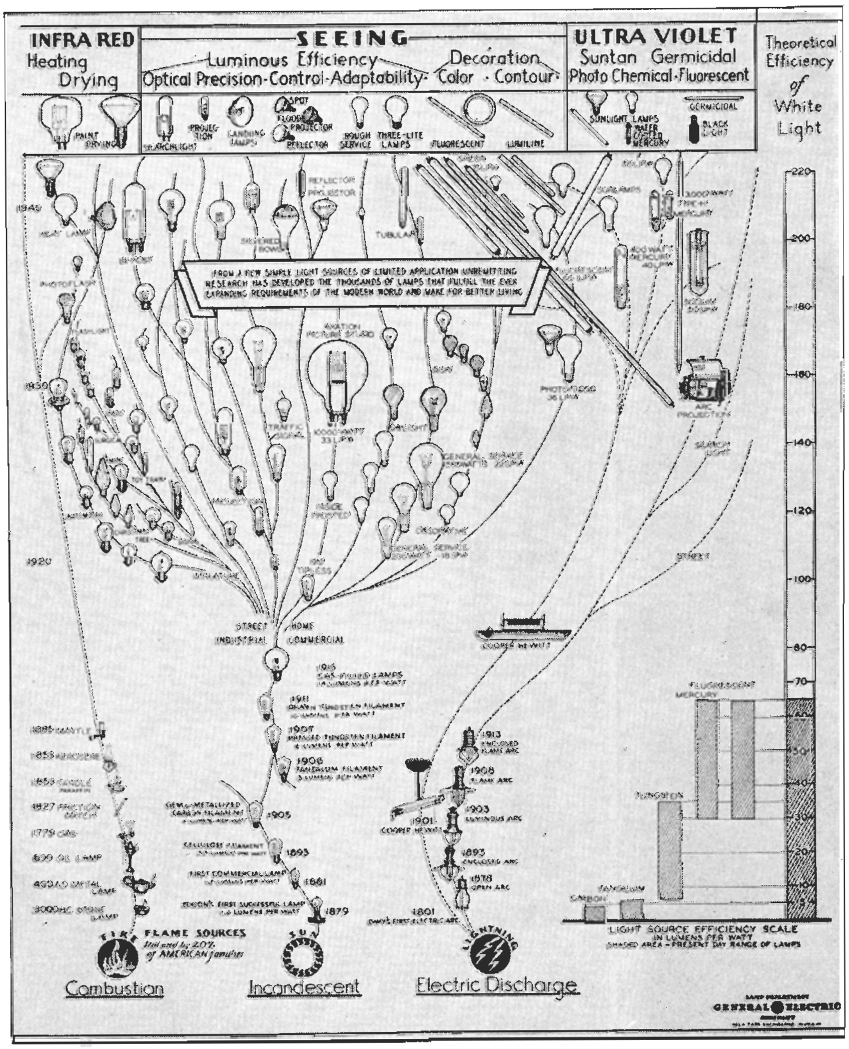
1941

**Above is an example of an early attempt to light streets with clusters of arc lamps mounted on very high towers. This system proved to be impractical, but offers evidence of early recognition of the need for more adequate street illumination.**

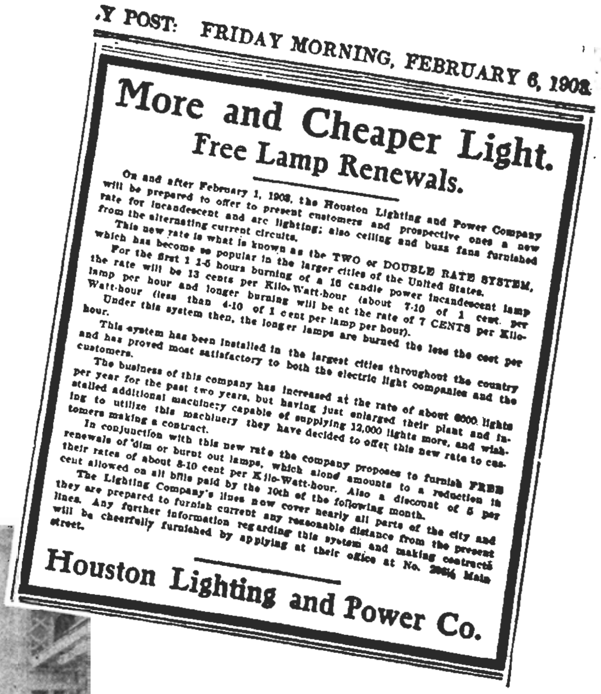
**The chart on the right illustrates the great strides which lighting and lamp development have made since the birth of the first practical incandescent lamp in 1879. The extent of lighting progress is evident by the variety of specialized light sources now available, and by the fact that 10 times as much light is obtained from the household bulb of today as from Edison's first lamp, at one-tenth of the lamp cost.**

As the pictures on these and subsequent pages indicate, the evolution of products, sales techniques, and community-building programs has not been accomplished without hard work, intelligent planning and continuing efforts to sell the benefits of "the electric way."

*Chart courtesy of General Electric Lamp Dept.*



# Pioneering In Power Utilization and Customer Service



.Y POST: FRIDAY MORNING, FEBRUARY 6, 1903.

## More and Cheaper Light.

### Free Lamp Renewals.

On and after February 1, 1903, the Houston Lighting and Power Company will be prepared to offer to present customers and prospective ones a new rate for incandescent and arc lighting; also ceiling and buzz fans furnished from the alternating current circuits.

This new rate is what is known as the TWO or DOUBLE RATE SYSTEM, which has become so popular in the larger cities of the United States.

For the first 1 1-5 hours burning of a 16 candle power incandescent lamp the rate will be 13 cents per Kilo-Watt-hour (about 7-10 of 1 cent. per lamp per hour and longer burning will be at the rate of 7 CENTS per Kilo-Watt-hour (less than 4-10 of 1 cent per lamp per hour).

Under this system then, the longer lamps are burned the less the cost per hour.

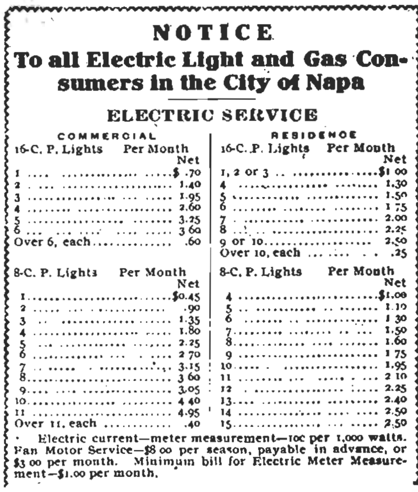
This system has been installed in the largest cities throughout the country and has proved most satisfactory to both the electric light companies and the customers.

The business of this company has increased at the rate of about 6000 lights per year for the past two years, but having just enlarged their plant and installed additional machinery capable of supplying 12,000 lights more, and wishing to utilize this machinery they have decided to offer this new rate to customers making a contract.

In conjunction with this new rate the company proposes to furnish FREE renewals of dim or burnt out lamps, which alone amounts to a reduction in their rates of about 8-10 cent per Kilo-Watt-hour. Also a discount of 5 per cent allowed on all bills paid by the 10th of the following month.

The Lighting Company's lines now cover nearly all parts of the city and they are prepared to furnish current any reasonable distance from the present lines. Any further information regarding this system and making contracts will be cheerfully furnished by applying at their office at No. 206½ Main street.

**Houston Lighting and Power Co.**



## NOTICE

### To all Electric Light and Gas Consumers in the City of Napa

**ELECTRIC SERVICE**

COMMERCIAL

| 16-C. P. Lights | Per Month Net |
|---|---|
| 1 | $ .70 |
| 2 | 1.40 |
| 3 | 1.95 |
| 4 | 2.60 |
| 5 | 3.25 |
| 6 | 3 60 |
| Over 6, each | .60 |

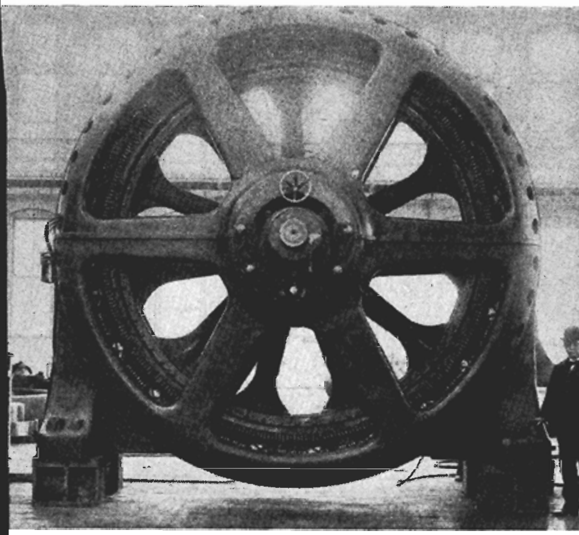
| 8-C. P. Lights | Per Month Net |
|---|---|
| 1 | $0.45 |
| 2 | .90 |
| 3 | 1.35 |
| 4 | 1.80 |
| 5 | 2.25 |
| 6 | 2 70 |
| 7 | 3.15 |
| 8 | 3 60 |
| 9 | 3.05 |
| 10 | 4 40 |
| 11 | 4.95 |
| Over 11, each | .40 |

RESIDENCE

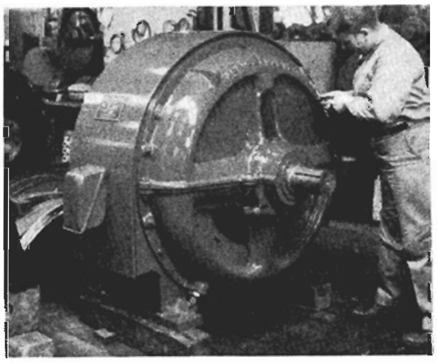
| 16-C. P. Lights | Per Month Net |
|---|---|
| 1, 2 or 3 | $1 00 |
| 4 | 1.30 |
| 5 | 1.50 |
| 6 | 1 75 |
| 7 | 2.00 |
| 8 | 2.25 |
| 9 or 10 | 2.50 |
| Over 10, each | .25 |

| 8-C. P. Lights | Per Month Net |
|---|---|
| 4 | $1.00 |
| 5 | 1.10 |
| 6 | 1 30 |
| 7 | 1.50 |
| 8 | 1.60 |
| 9 | 1 75 |
| 10 | 1.95 |
| 11 | 2 10 |
| 12 | 2.25 |
| 13 | 2.40 |
| 14 | 2.50 |
| 15 | 2.50 |

Electric current—meter measurement—10c per 1,000 watts. Fan Motor Service—$8 00 per season, payable in advance, or $3 00 per month. Minimum bill for Electric Meter Measurement—$1.00 per month.



*Photos courtesy of Allis-Chalmers Mfg. Co.*



**The 1903 announcement (left above) by the HOUSTON LIGHTING & POWER CO., is of historical significance in that this company was one of the first to establish free lamp renewal service. Above—rate schedule for about the same period, furnished by the VALLEJO ELECTRIC LIGHT & POWER CO., is based on the number of 16-candlepower and 8-candlepower lamps burned.**

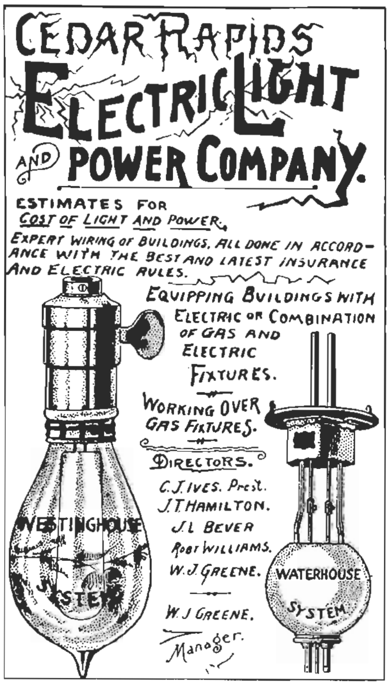
**The two views on the left offer striking evidence of the progress which has been made in induction motor design during the past 44 years. Both motors are rated at 400 hp 600 rpm. The massive unit of cast iron construction was built in 1903, and the contrasting unit in 1947.**

THE continuing electrification of America has required genuine leadership on the part of the power companies from the very start of the industry. The great contributions which electricity has made to society would have been considerably retarded had it not been for their energetic pioneering of new applications and untried devices.

Power company sales departments have had to develop markets for new appliances and new services and to create public acceptance for them to a point where they could be handled profitably by appropriate retail outlets.

Aggressive promotion of electrical use has been a major factor in the continual reduction of power costs to the consumer and has contributed in no small measure to the expansion of the retail appliance market to its present two billion dollar annual volume.

**Of considerable historic interest is the power company advertisement reproduced on the right, which appeared in the Cedar Rapids Gazette on January 1, 1889. The power company indicated is a predecessor of the IOWA ELECTRIC LIGHT & POWER CO.**



CEDAR RAPIDS ELECTRIC LIGHT AND POWER COMPANY.

ESTIMATES FOR COST OF LIGHT AND POWER.

EXPERT WIRING OF BUILDINGS, ALL DONE IN ACCORDANCE WITH THE BEST AND LATEST INSURANCE AND ELECTRIC RULES.

EQUIPPING BUILDINGS WITH ELECTRIC OR COMBINATION OF GAS AND ELECTRIC FIXTURES.

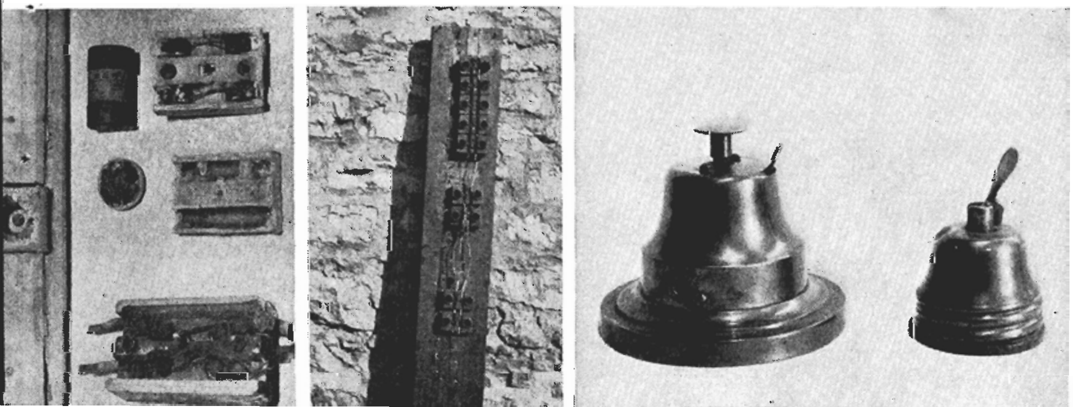
WORKING OVER GAS FIXTURES.

DIRECTORS.

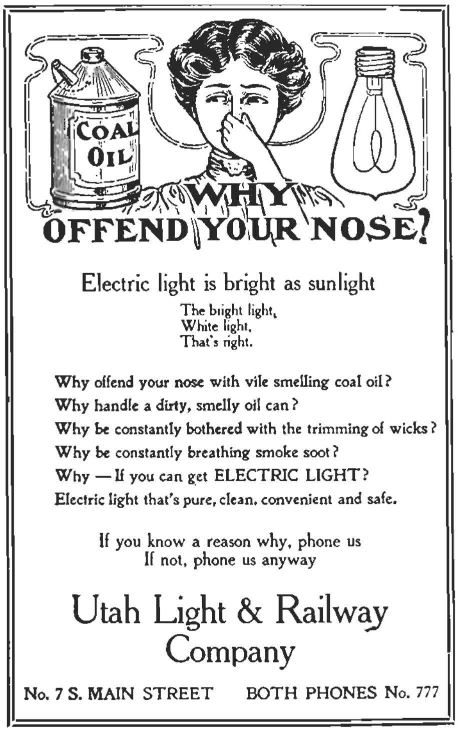
C. J. IVES. Prest.
J. T. HAMILTON.
J. L BEVER
ROBT WILLIAMS.
W. J. GREENE.

W. J GREENE.
Manager.

**The dangerous and inadequate character of house wiring in the early days is evident from the views below, which show the types of protective equipment and switches then available. On the left are wire fuses and fuse cutouts installed in New York in 1893. The center photo shows an installation of fuse cutouts dating back to about 1883. It will be noted that these early fuse blocks were all wood. Wood was also used extensively for sockets and switch handles. Two models of old-style lighting switches are shown on the right. Steady progress in the wiring device field has made possible the safety and convenience to be found in the wired home of today.**



**Competition with kerosene lighting still prevailed in 1906 when this advertisement appeared. A predecessor of the UTAH POWER & LIGHT CO. took this means to promote residential lighting.**



WHY OFFEND YOUR NOSE?

Electric light is bright as sunlight

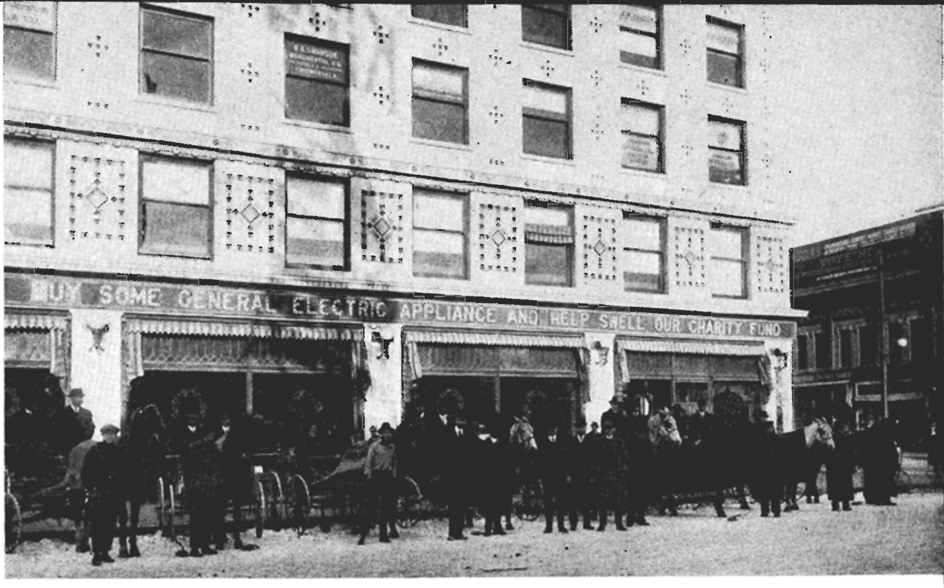
The bright light,
White light,
That's right.

Why offend your nose with vile smelling coal oil?
Why handle a dirty, smelly oil can?
Why be constantly bothered with the trimming of wicks?
Why be constantly breathing smoke soot?
Why — If you can get ELECTRIC LIGHT?
Electric light that's pure, clean, convenient and safe.

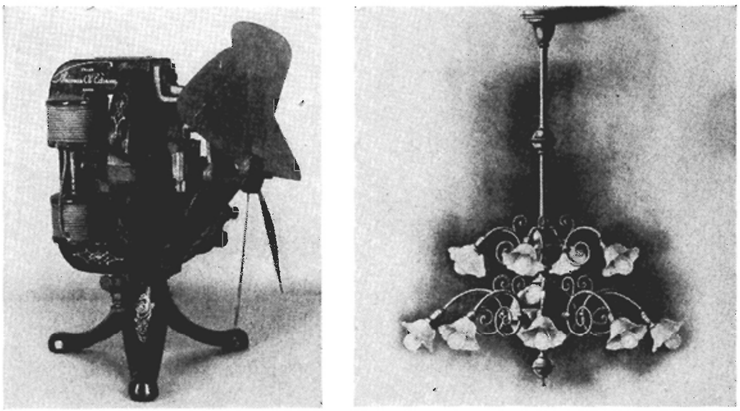
If you know a reason why, phone us
If not, phone us anyway

Utah Light & Railway
Company

No. 7 S. MAIN STREET BOTH PHONES No. 777


BUY SOME GENERAL ELECTRIC APPLIANCE AND HELP SWELL OUR CHARITY FUND

**Horse and Buggy Brigade (above) of the sales department of the PUBLIC SERVICE CO. OF COLORADO, one of the first power companies to conduct organized house-to-house load building campaigns. The electric iron was the popular load building item prior to 1910, and Denver was known throughout the industry for its high saturation of that appliance.**



**Primitive models of the electric fan and the ceiling lighting fixture, shown in the views right, are representative of some of the first attempts to introduce electrical conveniences into the home. The 12-light fixture was quoted at $69.40 installed, not including lamps.**

*Courtesy Edwin F. Guth Co.*

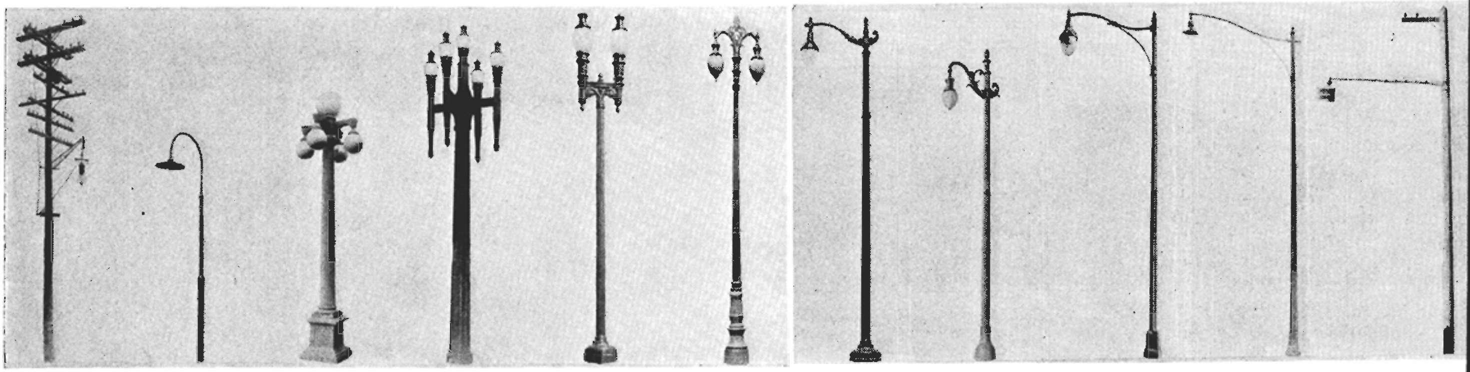
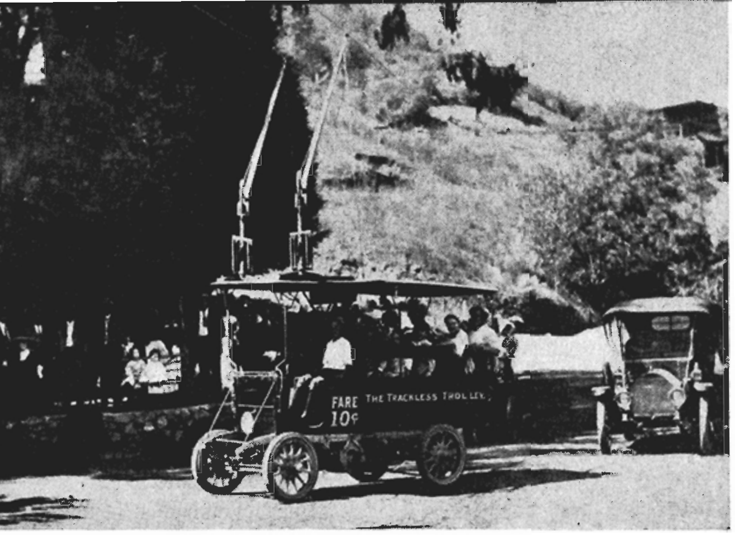


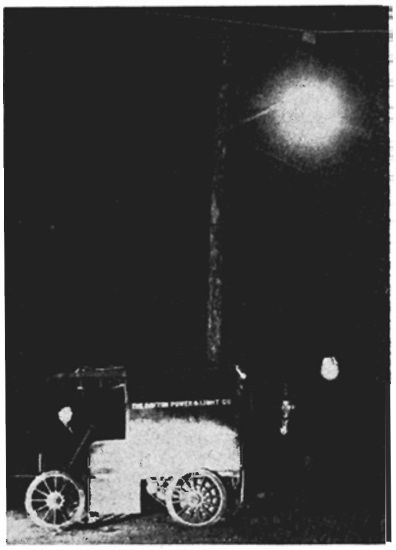
*Photo below courtesy of James R. Kearney Corp.*

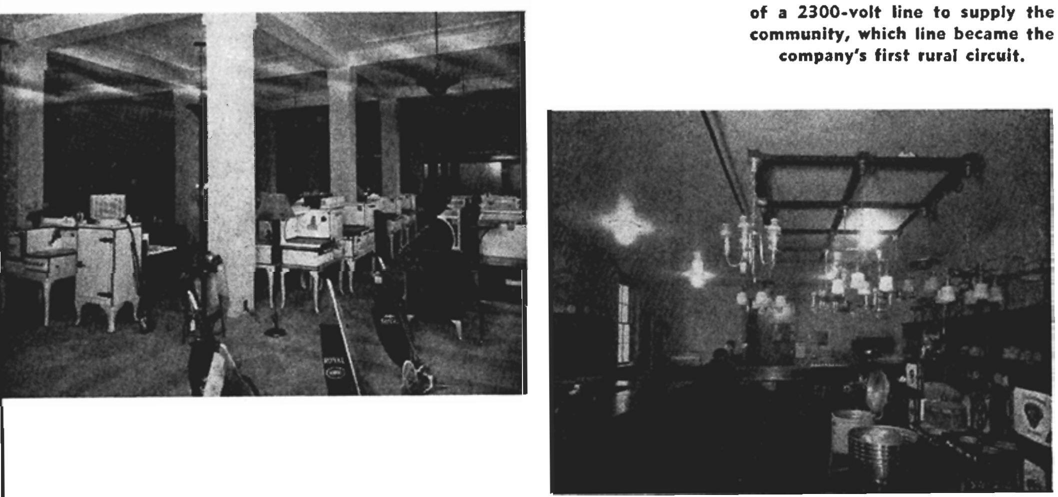
**The panel immediately above illustrates the progress in the design of street lighting standards and fixtures. The early carbon arc lamp suspended from a bracket attached to a distribution pole soon gave way to the goose-neck incandescent lamp standard with corrugated reflector. The units of the cluster-globe variety are still to be found in many parts of the country. Luminous arc units became popular for "white way lighting" about 1915. Still later, single and two-unit ornamental standards, scientifically designed and applied, were offered with the improved incandescent lamp for high level of street illumination. In the 1930's, mercury vapor and sodium vapor light sources were added to the line — the latter being popular for dangerous intersections, underpasses, bridges, and highway lighting. The 1912 street scene at the right is indicative of early design and installation practice in the street lighting field. The relatively short standard and long bracket, for support of the lighting fixture, differ greatly from modern designs based on standards of increasing height and spacing.**

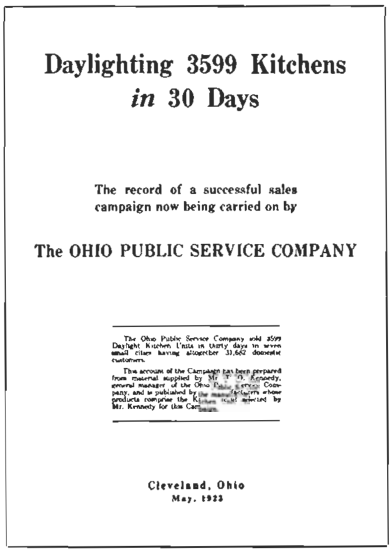


The first trolley coach in the U. S. (left) operated between Hollywood and Bungalowtown, Calif., in 1910. Note the solid tires and crude current collecting equipment. Today, more than 5,000 trolley coaches have been installed in, or are on order for 54 U. S. cities.

In 1912, the **DAYTON POWER & LIGHT CO.** utilized this service truck (right) to demonstrate a low voltage series street light in a rural community eight miles from Dayton. This pioneering sales effort resulted in the construction of a 2300-volt line to supply the community, which line became the company's first rural circuit.







# Daylighting 3599 Kitchens *in* 30 Days

The record of a successful sales
campaign now being carried on by

The OHIO PUBLIC SERVICE COMPANY

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The Ohio Public Service Company sold 3599 Daylight Kitchen Units in thirty days in seven small cities having altogether 31,682 domestic customers.

This account of the Campaign has been prepared from material supplied by Mr. T. O. Kennedy, general manager of the Ohio Public Service Company, and is published by the manufacturers whose products comprise the Kitchen Units selected by Mr. Kennedy for this Campaign.

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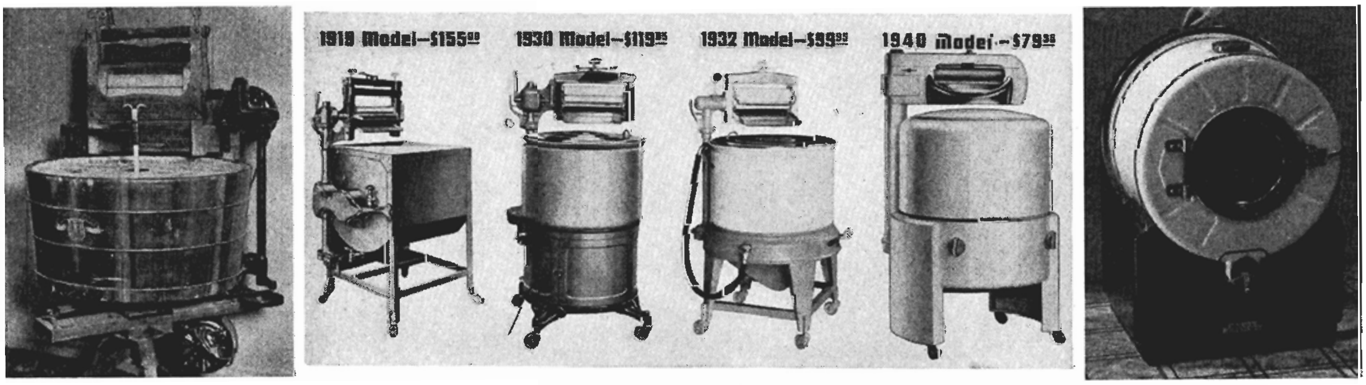
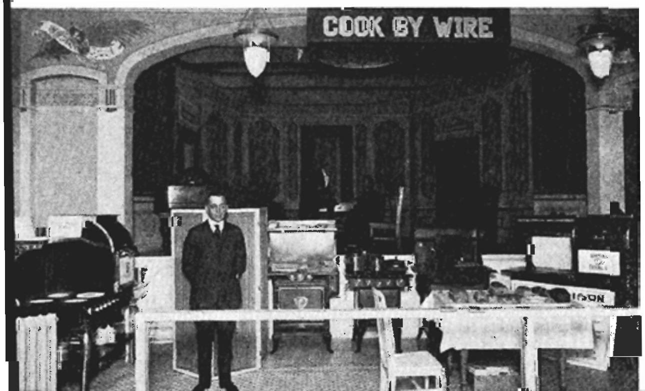
Cleveland, Ohio
May, 1923

When the picture at the left, above, was taken in 1930, in a district office of the **PUGET SOUND POWER & LIGHT CO.**, the appliance display was considered the very latest thing. The view in the center, taken about 1924-25, shows a **POTOMAC EDISON CO.** appliance store and office. It will be noted that lighting fixtures form a prominent part of the display and are indicative of the vigorous campaigns conducted by the power companies to promote improved home lighting. Reproduced on the right is the front cover of a booklet which reported the results of a notable kitchen lighting campaign of the **OHIO PUBLIC SERVICE CO.** in 1923.

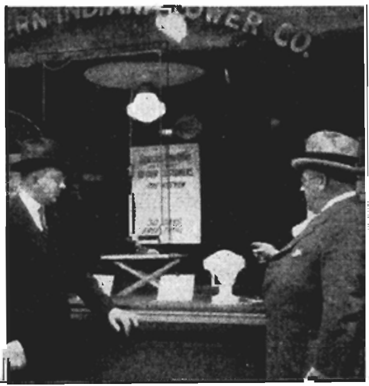


Progress in electric washer is depicted in the panel above. On the left is an early wringer-type model which served a customer of the **PORTLAND GENERAL ELECTRIC CO.** The group of wringer-type units (center) are indicative of design progress, coupled with cost reductions. The fully-automatic washer, right, denotes a further trend in washer development, which has freed the housewife from most of the labor associated with clothes washing.



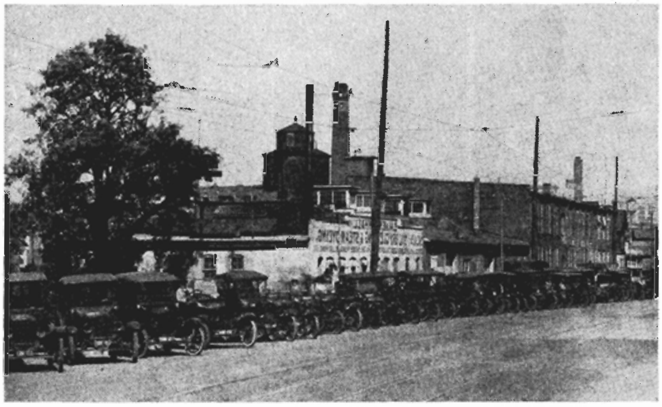
Remember the "Cook by Wire" slogan? At about the time of World War I, the **PUGET SOUND POWER & LIGHT CO.** conducted the electric cooking demonstration shown on the left.

Right — Kitchen lighting display window, a part of a 1924 sales campaign conducted by the **NORTHERN INDIANA POWER CO.** (now part of the **PUBLIC SERVICE CO. OF INDIANA, INC.**) Special units were featured by many power companies during this period to introduce the benefits of improved home lighting.

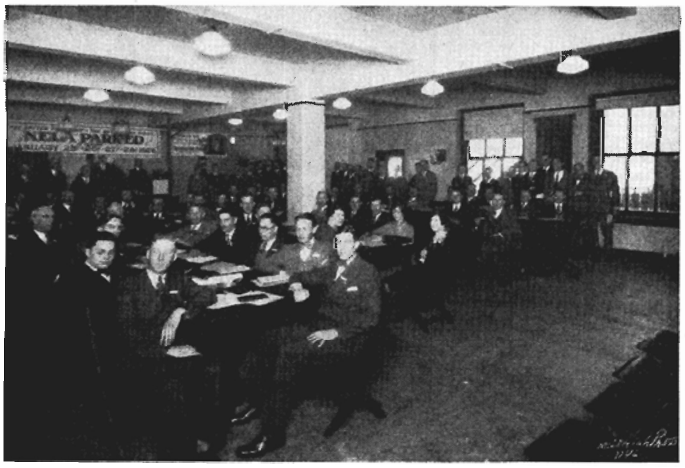

RN INDIANA POWER CO.

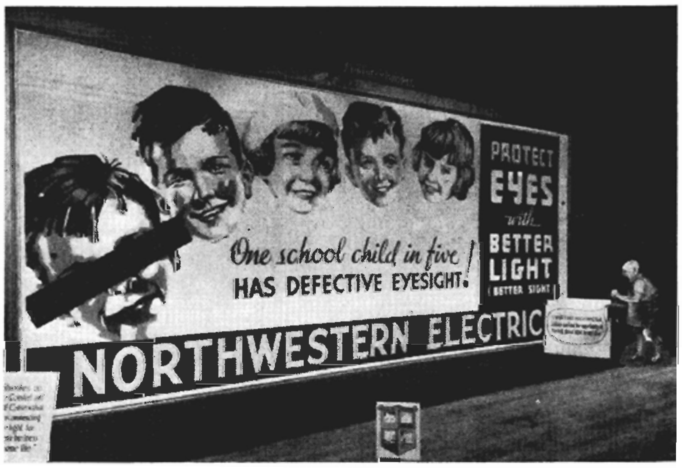
**Radio sets like the Zenith shown above were the marvel of the age back in the early '20's.**

**The 1923 automotive fleet of the DAYTON POWER & LIGHT CO., right, is indicative of the relatively large customer service organization maintained by that company in those days. Customer service has always played a vital role in power company operations and has required ever-expanding and specialized service activities.**



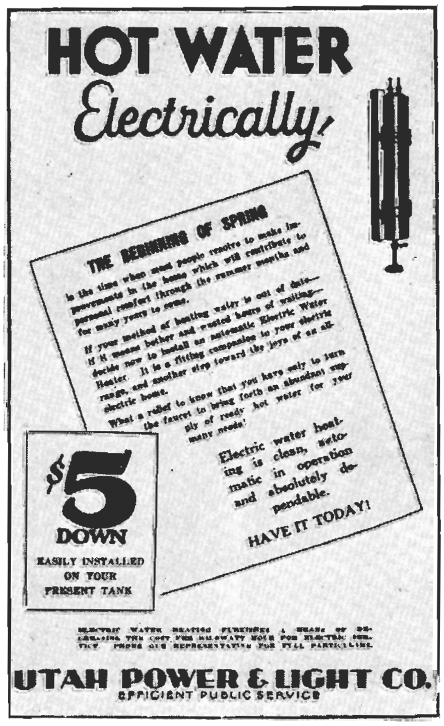
**Use of the electrical industry's "Better Light—Better Sight" slogan saw its beginning in this 1928 meeting (left, below) held in the Denver offices of the PUBLIC SERVICE CO. OF COLORADO. Extensive outdoor billboard advertising (below, right) was used by the NORTHWESTERN ELECTRIC CO. in 1933 as one of the opening guns of the company's tie-in with a national campaign for eye protection, through the use of proper lighting.**




PROTECT EYES with BETTER LIGHT (BETTER SIGHT)
One school child in five HAS DEFECTIVE EYESIGHT!
NORTHWESTERN ELECTRIC

**Improved, closed-type, electric range units being displayed in the utility showroom, below, were offered to the public in 1925, and promoted by a number of utilities to replace open-coil units. The development of protected cooking elements increased cooking speed and reduced service troubles.** *Photo courtesy Edwin L. Wiegand Co.*

**The 1930 newspaper ad, right, of the UTAH POWER CO., significantly stressed the fact that the addition of electric water heating was a means of decreasing the unit cost of electricity. Note that "clamp-on" heating elements were offered at that time. Today's water heater is scientifically engineered for maximum economy and efficiency.**



HOT WATER
Electrically!

THE BEGINNING OF SPRING

Is the time when most people resolve to make improvements in the home which will contribute to personal comfort through the summer months and for many years to come.

If your method of heating water is out of date—if it means bother and wasted hours of waiting—decide now to install an automatic Electric Water Heater. It is a fitting companion to your electric range, and another step toward the joys of an all-electric home.

What a relief to know that you have only to turn the faucet to bring forth an abundant supply of ready hot water for your many needs!

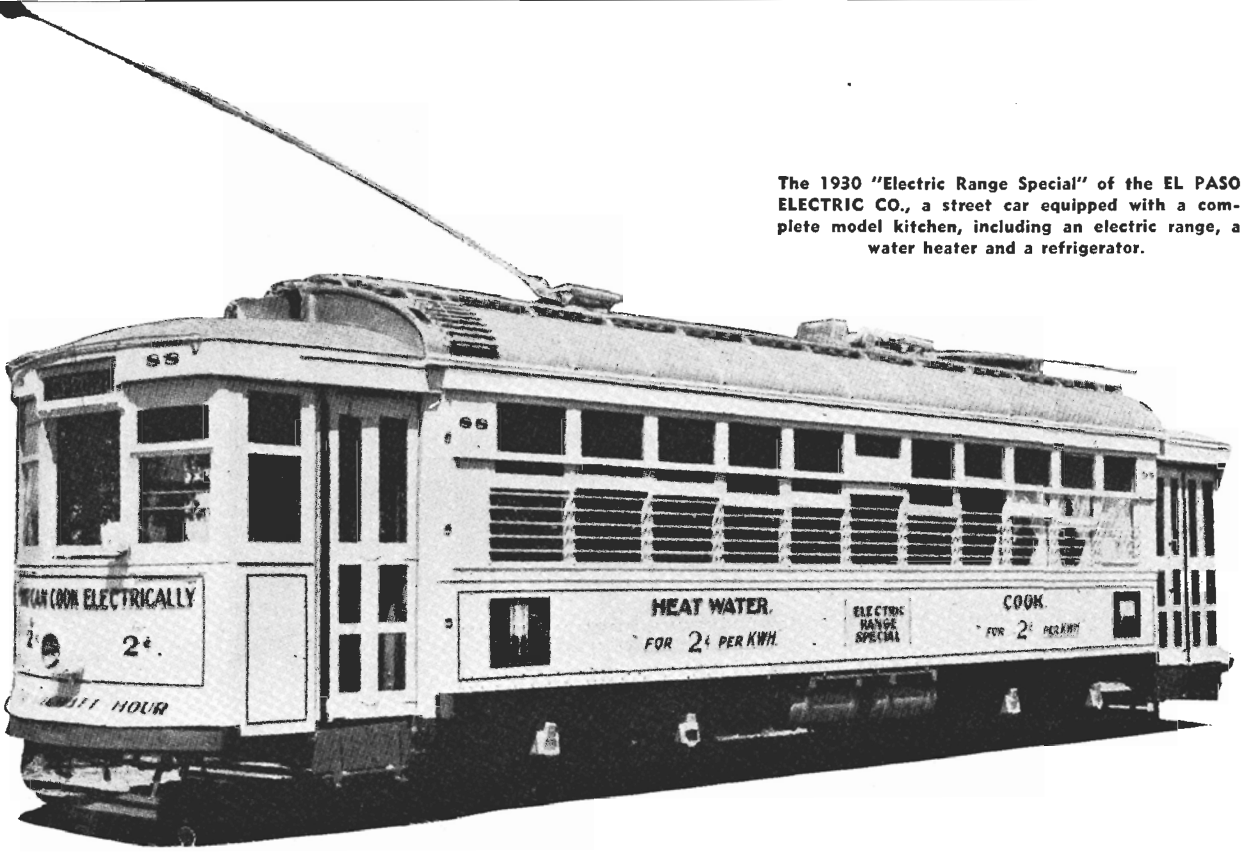
Electric water heating is clean, automatic in operation and absolutely dependable.

HAVE IT TODAY!

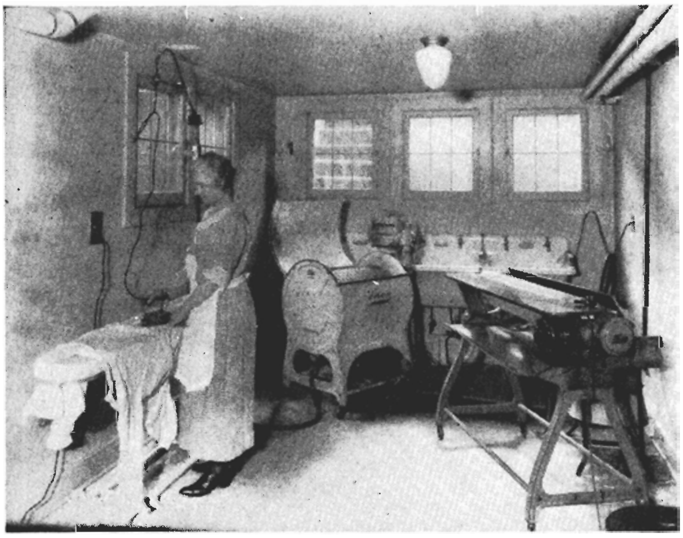
$5 DOWN
EASILY INSTALLED ON YOUR PRESENT TANK

ELECTRIC WATER HEATING FURNISHES A MEANS OF DECREASING THE COST PER KILOWATT HOUR FOR ELECTRIC SERVICE. PHONE OUR REPRESENTATIVE FOR FULL PARTICULARS.

UTAH POWER & LIGHT CO.
EFFICIENT PUBLIC SERVICE

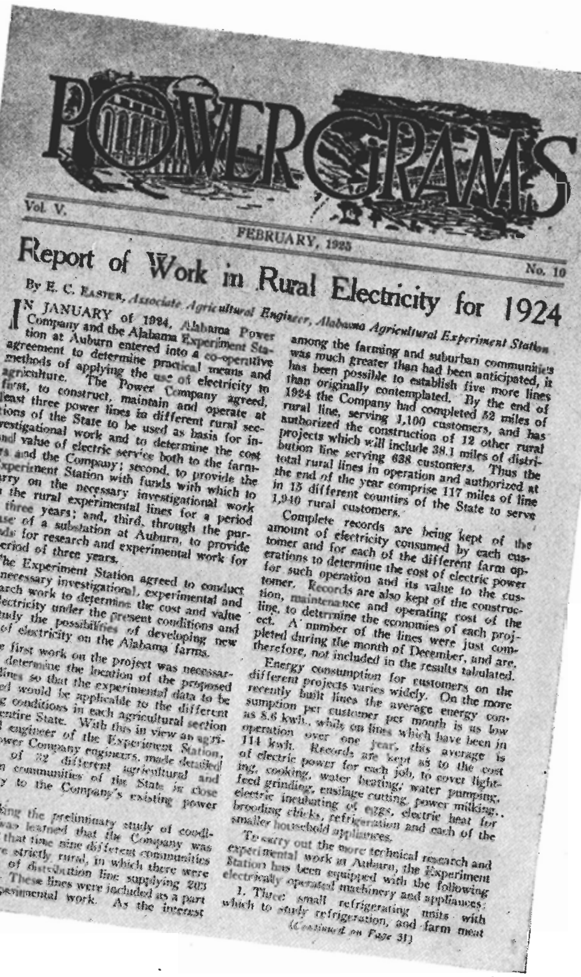


**The 1930 "Electric Range Special" of the EL PASO ELECTRIC CO., a street car equipped with a complete model kitchen, including an electric range, a water heater and a refrigerator.**



**This home laundry was the latest thing in washday convenience in the middle 1920's.**

**1925—Below—Pioneer mobile demonstration unit containing appliances and electric equipment for electrified farming. Utilizing a truck and trailer, and jointly financed by Michigan State College and the CONSUMERS POWER CO., this unit accelerated the education of Michigan farmers in the possibilities of electrical applications.**



POWERGRAMS

Vol. V. FEBRUARY, 1925 No. 10

Report of Work in Rural Electricity for 1924

By E. C. Easter, *Associate Agricultural Engineer, Alabama Agricultural Experiment Station*

IN JANUARY of 1924, Alabama Power Company and the Alabama Experiment Station at Auburn entered into a co-operative agreement to determine practical means and methods of applying the use of electricity to agriculture. The Power Company agreed, first, to construct, maintain and operate at least three power lines in different rural sections of the State to be used as basis for investigational work and to determine the cost and value of electric service both to the farmers and the Company; second, to provide the Experiment Station with funds with which to carry on the necessary investigational work on the rural experimental lines for a period of three years; and, third, through the purchase of a substation at Auburn, to provide funds for research and experimental work for a period of three years.

The Experiment Station agreed to conduct the necessary investigational, experimental and research work to determine the cost and value of electricity under the present conditions and to study the possibilities of developing new uses of electricity on the Alabama farms.

The first work on the project was necessarily to determine the location of the proposed rural lines so that the experimental data to be obtained would be applicable to the different existing conditions in each agricultural section of the entire State. With this in view an agricultural engineer of the Experiment Station, with Power Company engineers, made detailed surveys of 22 different agricultural and suburban communities of the State in close proximity to the Company's existing power lines.

In making the preliminary study of conditions it was learned that the Company was serving at that time nine different communities which were strictly rural, in which there were 26.8 miles of distribution line supplying 203 customers. These lines were included as a part of the experimental work. As the interest among the farming and suburban communities was much greater than had been anticipated, it has been possible to establish five more lines than originally contemplated. By the end of 1924 the Company had completed 52 miles of rural line, serving 1,100 customers, and has authorized the construction of 12 other rural projects which will include 38.1 miles of distribution line serving 638 customers. Thus the total rural lines in operation and authorized at the end of the year comprise 117 miles of line in 15 different counties of the State to serve 1,940 rural customers.

Complete records are being kept of the amount of electricity consumed by each customer and for each of the different farm operations to determine the cost of electric power for such operation and its value to the customer. Records are also kept of the construction, maintenance and operating cost of the line, to determine the economies of each project. A number of the lines were just completed during the month of December, and are, therefore, not included in the results tabulated.

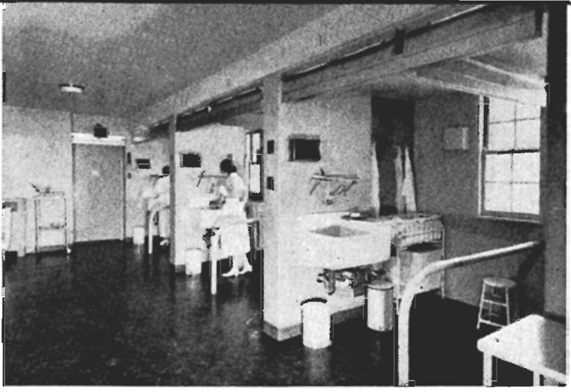
Energy consumption for customers on the different projects varies widely. On the more recently built lines the average energy consumption per customer per month is as low as 8.6 kwh., while on lines which have been in operation over one year, this average is 114 kwh. Records are kept as to the cost of electric power for each job, to cover lighting, cooking, water heating, water pumping, feed grinding, ensilage cutting, power milking, electric incubating of eggs, electric heat for brooding chicks, refrigeration and each of the smaller household appliances.

To carry out the more technical research and experimental work at Auburn, the Experiment Station has been equipped with the following electrically operated machinery and appliances:

1. Three small refrigerating units with which to study refrigeration, and farm meat

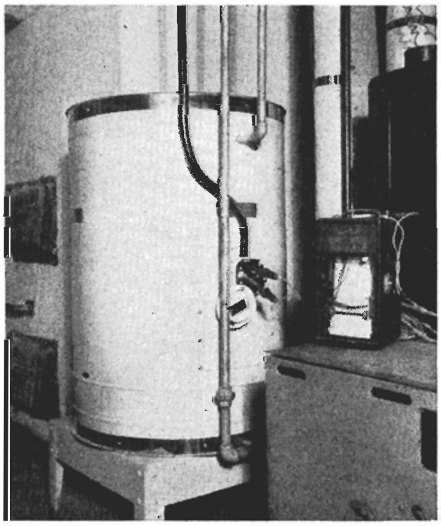
(Continued on Page 31)

**The ALABAMA POWER CO. was an early pioneer in the application of electricity to agriculture, as indicated by this 1924 report. This work was carried out under a cooperative agreement with the Alabama Experimental Station and demonstrates that the power companies were alert to the possibilities of rural electrification long before federal government sponsorship of that activity.**



Specialized light sources for the protection of the health of children are being used in ever-increasing numbers, as a result of intensive promotional efforts by both the manufacturers and the power companies. The schoolroom on the left, served by the **DETROIT EDISON CO.**, is equipped with ultraviolet lamps, for the bactericidal irradiation of the air in the room, and modern sight-saving fluorescent lighting. Left, above, is a physical therapy room equipped with nine sun lamps, for physically handicapped children in the territory served by the **OHIO PUBLIC SERVICE CO.** Above, germicidal lamps installed in front of the cubicles create a curtain of germ-killing ultra-violet light to protect the babies in this hospital, served by **PUBLIC SERVICE CO. OF NORTHERN ILLINOIS.**

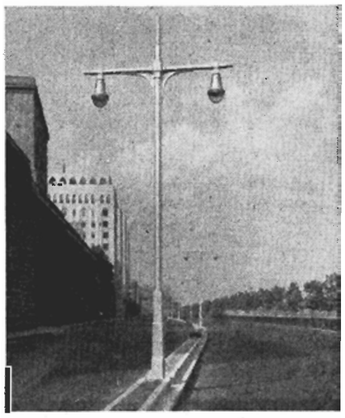
The New York World's Fair will ever be remembered for the striking lighting effects created through the use of newly developed gaseous light sources, particularly the fluorescent lamp. This brilliant display signalized the beginning of a new and more colorful era of illumination.



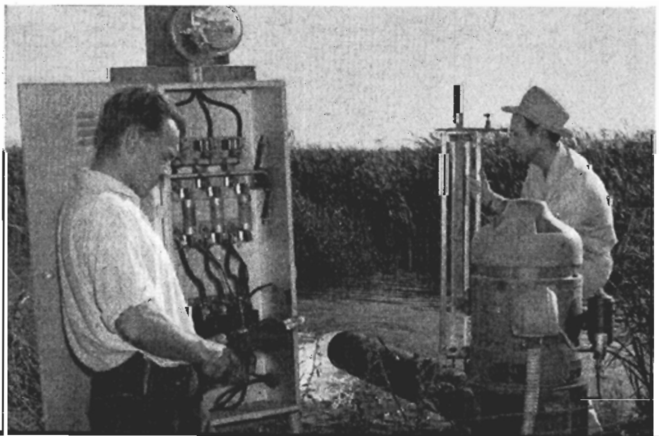
In 1927 the **NORTHERN STATES POWER CO.** installed low-wattage off-peak storage-type water heaters in a number of employee homes to determine the economic feasibility of this load. By developing off-peak loads, power companies were able to reduce materially the overall average cost of electricity to the customer because off-peak use enabled greater output of power without increase in the installed generating capacity.

New York City's East River Drive (right) is illuminated by twin-light standards; one of the latest of the prewar installations. The more recent trend is toward a higher mounting height for the luminaire and greater simplicity in the design of the standard.

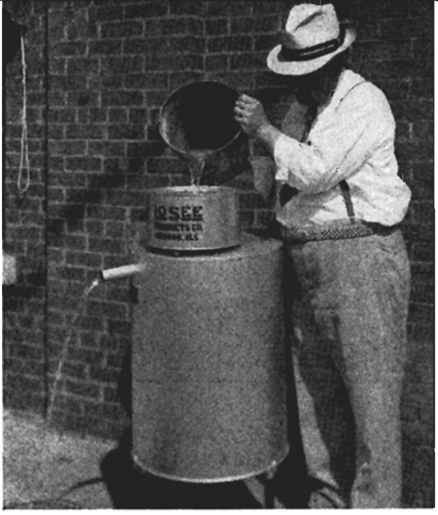
*Photo courtesy Daunt Corp.*



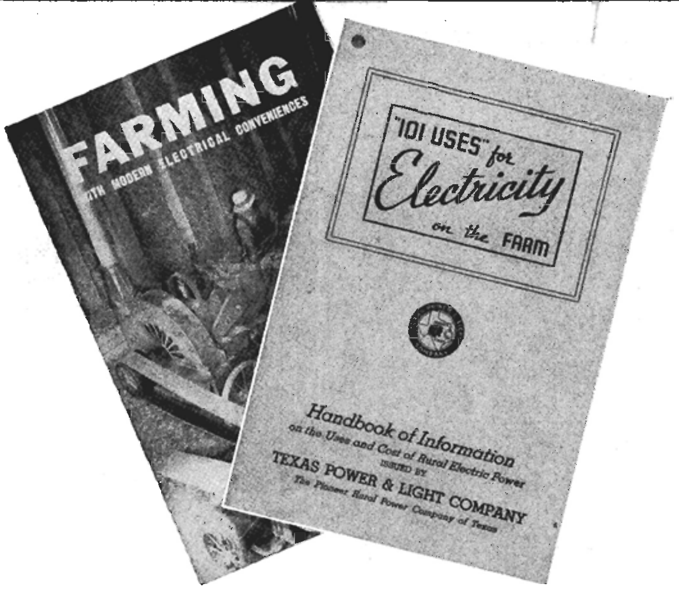
The **PACIFIC GAS & ELECTRIC CO.** crew, below, is testing the efficiency of a farm motor and irrigation pump, a free service offered to its customers. Correction of any electrical or mechanical deficiencies disclosed by such tests insures a maximum return on the customer's investment.



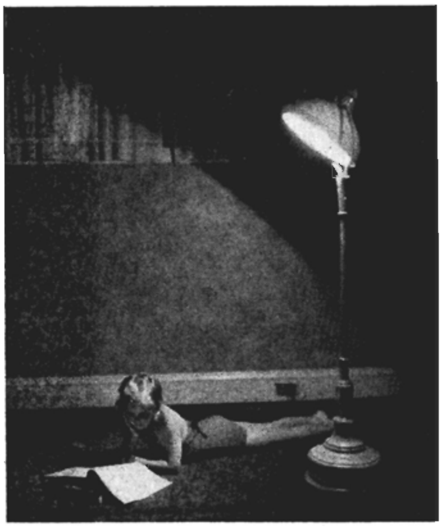
The "white-way" lighting (right) in Phoenix, Ariz., served by the **CENTRAL ARIZONA LIGHT & POWER CO.**, is a commendable example of the type of high-level street illumination which has sharply reduced nighttime traffic fatalities, expedited traffic flow and reduced crime. *Photo courtesy Union Metal Mfg. Co.*



Development of the displacement type of electric water heater (above), for milk houses on dairy farms, resulted from efforts of the **WISCONSIN POWER & LIGHT CO.** to obtain a heater low in cost and efficient in operation. This has proved to be a satisfactory device and is another evidence of utility efforts to support equipment developments which will benefit the farmer


FARMING
WITH MODERN ELECTRICAL CONVENIENCES
"101 USES" for Electricity on the FARM
Handbook of Information
on the Uses and Cost of Rural Electric Power
ISSUED BY
TEXAS POWER & LIGHT COMPANY
The Pioneer Rural Power Company of Texas

The two booklets shown above, prepared by the **PENNSYLVANIA POWER CO.** and the **TEXAS POWER & LIGHT CO.**, are typical of power companies' efforts in farm electrification education. By this means, farmers are supplied with authentic and reliable data obtained through experience of farm customers and substantiated by extensive research by college staffs.

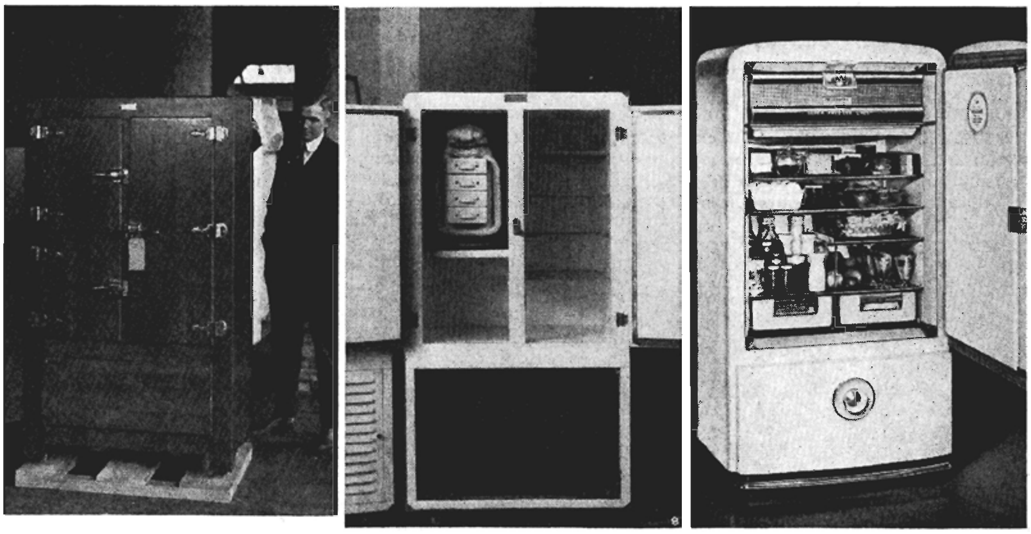


(Above) In 1929 a new electrical development brought the healthful ultra-violet radiations of the sun into the home through the medium of the sun lamp.

For the past 25 years, the **DETROIT EDISON CO.** has maintained a customer order board which is never closed, to receive requests for service, to receive complaints, to take orders for repairs, or to dispatch service men in the event of trouble. Facilities in 1922 are shown on the right, and present-day facilities above.

Significant steps in the evolution of the electric refrigerator are pictured in these views. The refrigerator on the immediate right, the first unit of its kind, was built in 1920. The center view shows the first of the metal cabinet type, introduced in 1924, during which year the first porcelain cabinet was also introduced. The unit on the far right incorporates the many features which have combined to make the modern electric refrigerator an indispensable item in the home.

*Photos courtesy Frigidaire Div., General Motors Corp.*



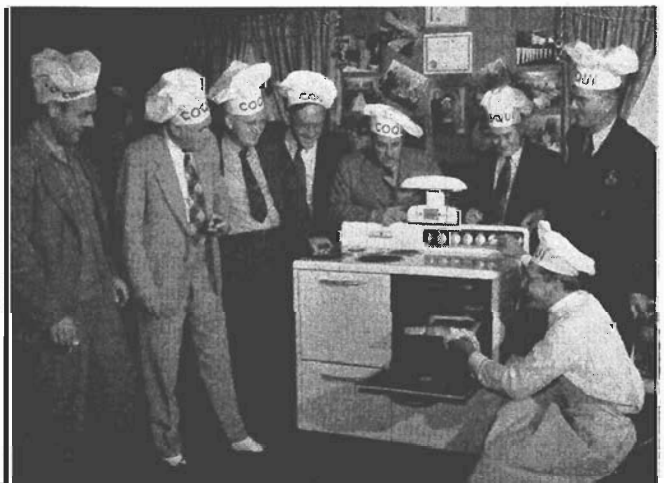
**Power company lighting engineers have added to the hours of outdoor recreation for the public by active promotion of lighting for night sports. The four views above are typical of the highly specialized lighting of extensive sport areas such as golf practice fairways (above, left), soft-ball parks (above, right), and the ball park (lower, left). (Below, right)—The miniature golf course—remember?** *Photos courtesy General Electric Co.*

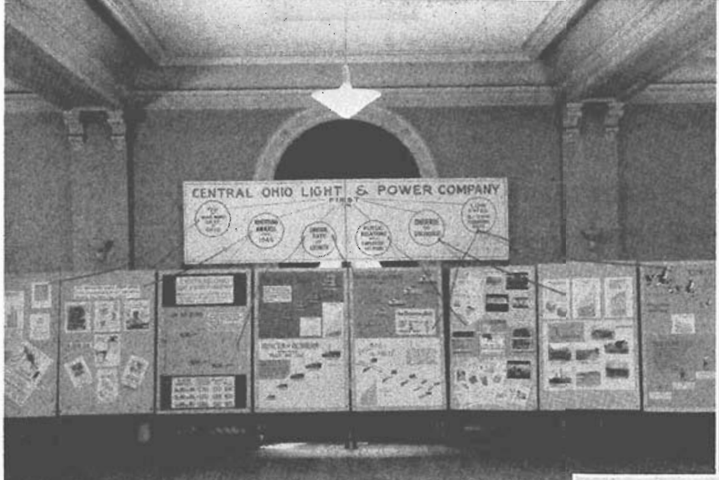
**Appliance rental plans were developed and widely used to rebuild load lost during the depression and to introduce the advantages of electrical appliances to many who otherwise could not have afforded the outlay for equipment. Public interest in the idea is shown by the crowd around a booth of the KANSAS CITY POWER & LIGHT CO. at a 1936 food show, when electric ranges were offered for rent or sale at $1.25 per month.**

**Night lighting of poultry farms such as this one (below), on the PUGET SOUND POWER & LIGHT CO.'s system, brings extra egg production. This development was only one of many farm applications pioneered by the power companies to make farm operations easier and more profitable.**

**Model all-electric homes, like that shown below, were another means of introducing modern electrical conveniences to the people of America in the 1930's.**

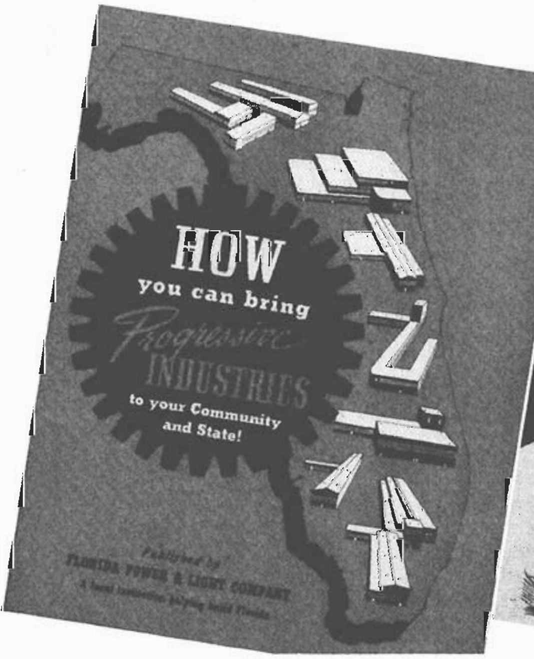
**The "Order of the Coqui" started by the TAMPA ELECTRIC CO., created nationwide male interest in electric cooking.**



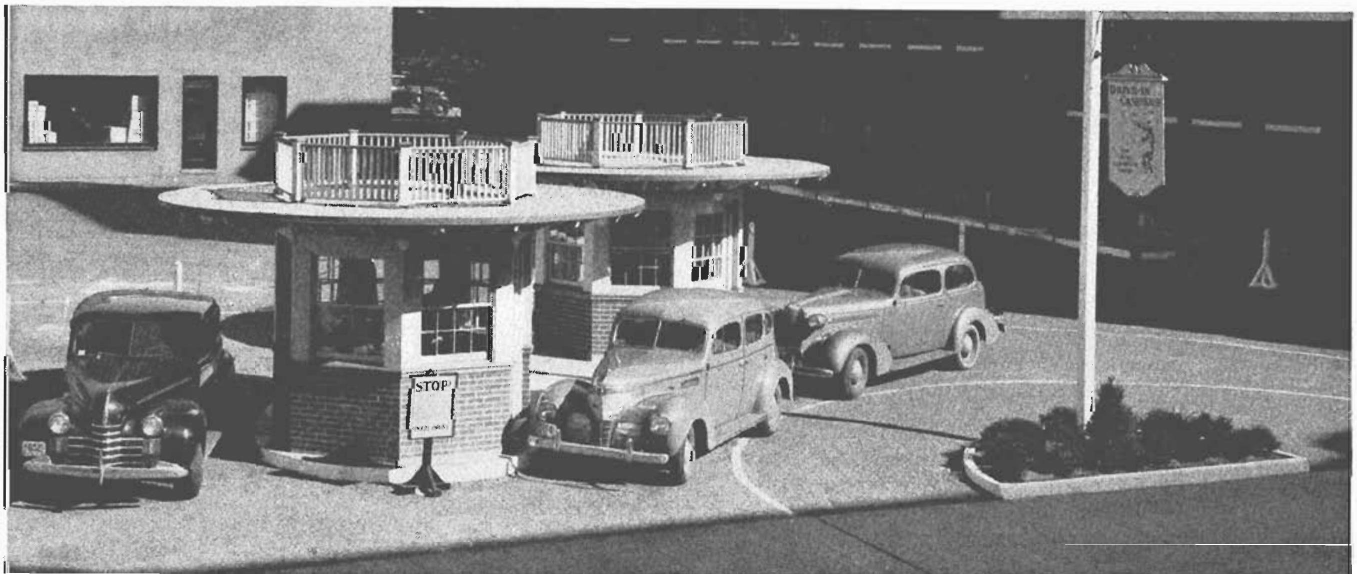


Community betterment activities by the power companies take many forms. The display shown directly above has been widely used by the **CENTRAL OHIO LIGHT & POWER CO.** to present, to those people interested in the company, an understandable picture of company operations and the territory it serves. Building sales for local merchants through promoting better store lighting is another activity that results in improved civic appearance, as illustrated by the apparel shop (above, right), on the lines of the **PUBLIC SERVICE CO. OF NORTHERN ILLINOIS.** The **IOWA ELECTRIC CO.** utilizes outdoor billboard advertising, such as shown on the right, as a part of its efforts to help build business and civic pride in the communities it serves.

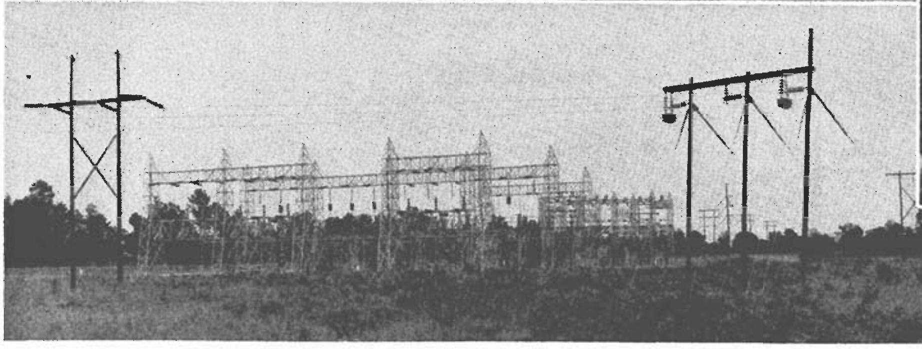
The leading part taken by power companies in attracting new industries to the communities they serve is illustrated by the booklets shown here. That of the **FLORIDA POWER & LIGHT CO.**, for local business organizations in its territory, describes methods which have been found effective in persuading industrial executives to locate new plants, branch plants, or factories, in their communities. The **MISSISSIPPI POWER & LIGHT CO.** has made a nation-wide distribution of the booklet on the far right, which contains an impressive summary of Mississippi's natural resources, economic advantages, and potential as a growing market.



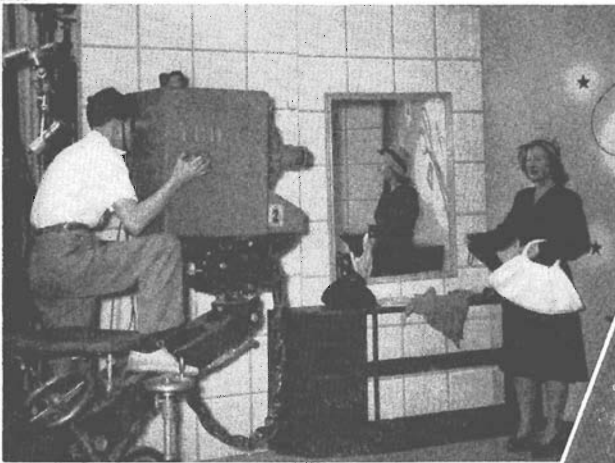
In 1941, the **UNITED ILLUMINATING CO.** installed the drive-in cashier booth shown below, as a convenience to its customers. These booths have been very popular, as they enable customers to pay their bills without leaving their cars, and without having to seek out space for parking.



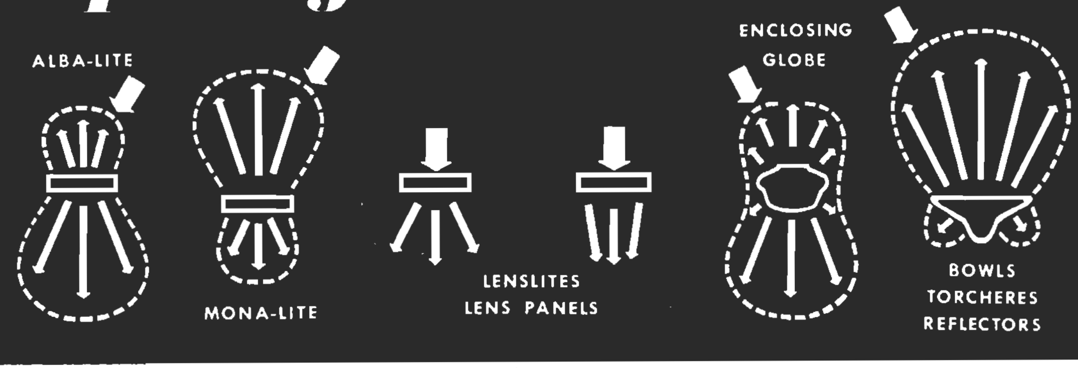
Wartime contributions of the business-managed electric utilities included not only "pool" operations and other means by which the unprecedented load demands were met, but also the collection of mountains of critical materials in salvage drives, the use of bicycles to reduce automotive fleet operations, and cooperation in the enforcement of blackouts. Some of these utility operations are pictured in the adjacent scenes. Shown in the three photos to the left are **PACIFIC POWER & LIGHT CO.**'s wartime bicycle fleet, the **PENNSYLVANIA POWER CO.**'s blackout crew, and the **SOUTHWESTERN GAS & ELECTRIC CO.**'s substation which served as a hub in the Southwestern Power Pool. The **ARKANSAS POWER & LIGHT CO.** representative shown below is standing in one of the many scrap piles that company built up by a systematic canvassing of its properties.



1947—Power companies continue to pioneer new services for the public. Some of their more important post-war load building plans are designed to encourage commercial use of the heat pump and to obtain widespread acceptance of the television service. The **FLORIDA POWER CORP.** has obtained firsthand and authentic data on one type of heat pump, as shown on the left below, by placing several such units in its own offices where it can be seen by and discussed with, prospective users. The **AMERICAN GAS & ELECTRIC** system has played a leading role in the development and promotion of the heat pump, as indicated by the progress report reproduced on the right below. The studio scene is indicative of the pioneering work done by the **PHILADELPHIA ELECTRIC CO.** in sponsoring a television program as a means of popularizing television service in its customers' homes.



# You specify...

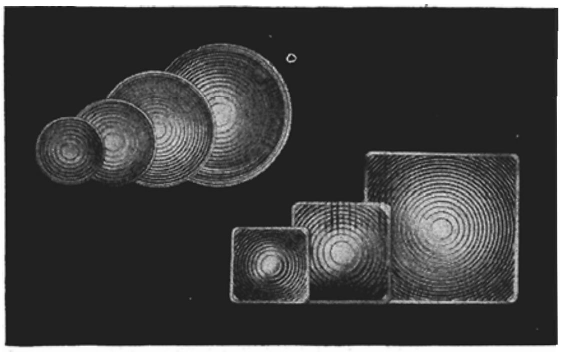


# CORNING ENGINEERED LIGHTINGWARE DELIVERS THE LIGHT YOU NEED

*High transmission, low reflection*—ALBA-LITE is a highly efficient, translucent glass that is supplied flat or bent to the shape you specify.

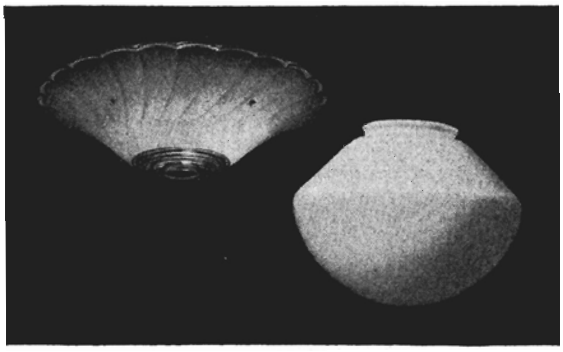
*Low transmission, high reflection*—MONA-LITE is a dense opal glass in rolled sheet form . . . supplied flat to specifications.

*Balanced lighting*—used separately or in combination, ALBA-LITE and MONA-LITE provide maximum flexibility in fixture design and light diffusion. Both ALBA-LITE and MONA-LITE achieve diffusion or reflection through its composition rather than surface treatment.



*Wide or concentrated light beam patterns*—Lenslites are available in many sizes, both round and square for wide angle or concentrated beam spreads.

*Light control with low panel brightness*—Lens panels are available in a wide variety of lengths and widths to permit maximum flexibility in fixture design.



*Diffusion*—Monax brand enclosing globes provide outstanding performance on general diffuse lighting applications.

*Reflection and diffusion*—I.E.S. type reflectors possess high reflecting properties and are ideally suited for table, bridge and floor lamps.

*Pleasing and efficient illumination*—Corning Lighting Bowls and ordinary globes are designed to provide attractive and effective lighting fixtures for general residential and commercial use.

CORNING means research in GLASS

T.M. REG. CORNING U.S. PAT. OFF.

**CORNING GLASS WORKS • CORNING, N. Y.**
*SALES OFFICES: NEW YORK • CHICAGO • SAN FRANCISCO*
**LIGHTINGWARE**

TECHNICAL PRODUCTS DIVISION: LIGHTINGWARE • GAUGE GLASSES • GLASS PIPE • SIGNALWARE
LABORATORY GLASSWARE • OPTICAL GLASS • GLASS COMPONENTS

E P P

ECONOMY PURCHASE

PLAN

# THE ECONOMY PURCHASE PLAN

**Accelerates appliance sales for electric utility companies.**

**Eliminates tie-up of working capital in appliance inventory or in carrying time-payment customers.**

**Improves working relations with local independent dealers and retail customers.**

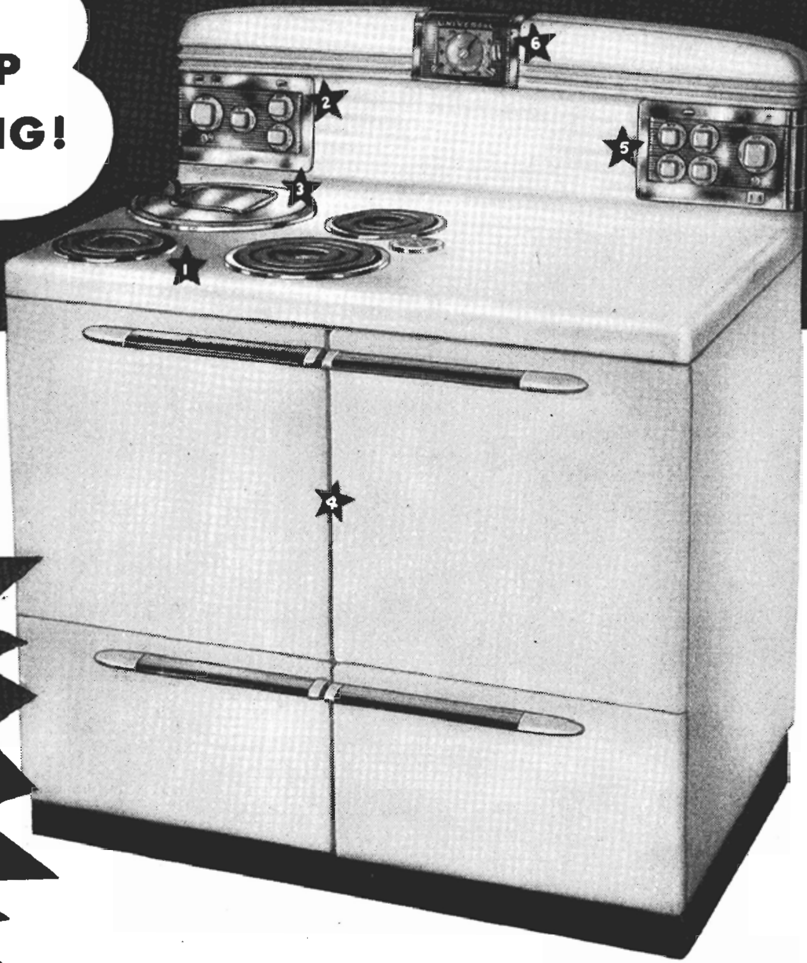
**Thirteen years of co-operation with major utilities in the South, East and North Central States has proved its success in building appliance sales . . . load . . . and goodwill.**

*Write for Details to Department E. P. P. or telephone*
*AShland 4-5400 in New York City or CAlvert 4100 in Baltimore*

**COMMERCIAL CREDIT COMPANY**
**BALTIMORE**

# IT'S NEW... IT'S DRAMATIC...

**FOR LEADERSHIP IN LOAD BUILDING!**



*The UNIVERSAL "Speedliner"*

*The Nation's Fastest Range... Out in Front by Two Full Years!*

## It's Completely Automatic!!

### Packed with Features for Salesational Selling

**1. New Super-Heat Surface Units** ...new "Monotube" construction gives tops in efficiency . . . greatest ease in cleaning.

**2. New Mult-I-Heat Control** . . . now you can get any degree of heat desired for surface cooking—pioneered by Universal.

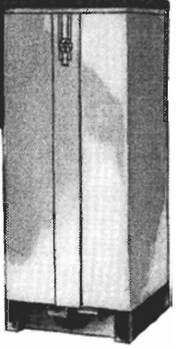
**3. New Thermo-Chef Auxiliary Oven** . . . does completely automatic cooking when large oven capacity is not required. Heated by side-wound unit and thermostatically controlled.

**4. New Tru-Bake Automatic Oven** . . . new "push-button" Preheat Switch and new oven-exposed thermostat combine to give even temperature control through successive bakings. Completely automatic with new easy-to-use timer.

**5. New Tel-A-Switch Panel** with Signalite Control . . . for easy identification and extra convenience. Ovens automatically switch from preheat to bake.

**6. New Automaticook** for Completely Automatic Cooking . . . controlled by Select-A-Trol . . . amazingly efficient and easy to use . . . eliminates oven watching.

*ALSO UNIVERSAL WATER HEATERS*



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